

Spring 5-2013

Sedimentology and Geochemistry of Weisner Formation, Bartow County, Georgia

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SEDIMENTOLOGY AND GEOCHEMISTRY OF WEISNER FORMATION,
BARTOW COUNTY, GEORGIA

by

RHODA OLAYINKA POPOOLA

Under the Direction of Dr. Daniel M. Deocampo

ABSTRACT

The study area is located along Highway 20 east Cartersville Georgia, where outcrops of the Weisner Formation are exposed. The section consists of two main facies, the sandstone facies and shale facies. Parallel lamination and cross stratification are commonly observed sedimentary structures at this location. Petrographic study reveals that the grains in the sandstone are dominantly quartz, and to a smaller extent feldspar and mica. The shale facies is rich in Al_2O_3 and K_2O compared to the sandstone facies. No fossil is observed in any of the two facies. Petrographic studies also indicate igneous, metamorphic, and sedimentary source rocks for these clastic rocks. The shale facies is very rich in mica, with muscovite and some kaolinite. Lithologic features and grain size suggest that the Weisner Formation was probably deposited in a shallow marine environment.

INDEX WORDS: Sedimentology, Mineralogy, Georgia, Weisner Formation

SEDIMENTOLOGY AND GEOCHEMISTRY OF WEISNER FORMATION,
BARTOW COUNTY, GEORGIA

by

RHODA OLAYINKA POPOOLA

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

Master of Science

in the College of Arts and Sciences

Georgia State University

2013

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Rhoda Olayinka Popoola
2013

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BARTOW COUNTY, GEORGIA

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College of Arts and Sciences

Georgia State University

May 2013

DEDICATION

I dedicate my Thesis to God Almighty, the source of my dreams, strength and hope. Special hug and kisses to my dearest husband and best friend Engr. Solomon Ayodele Popoola, for loving, guiding and growing old with me. To my lovely children Samuel Iyiola Popoola and Ruth Ikelayo Popoola, you all bring smile and peace to my world.

To my late mother Mrs. Rachael Ajironke Olorunlagba words cannot express my appreciation and joy for your efforts on me. You were the best, and I could not have asked for a better mother....You will always be remembered.

To my siblings, In-laws, and friends; you are always a special support and pillar of grace.

ACKNOWLEDGEMENTS

My profound appreciation to my Thesis advisor Dr. Daniel M. Deocampo for his time, effort and contributions in making this project a success. To the committee members Dr.W.Crawford Elliott and Dr. Hassan A. Babaie; thank you so very much for your tireless efforts and awesome contributions. Special thanks to all the faculty and staff members of Geosciences Department, at Georgia State University, Atlanta, GA. for your unweaving support, use of laboratories and instruments and also for giving me graduate assistantship and stipend to help with my studies .Thanks to Rebecca Pickering for your assistance with the XRD analysis, Ginny Mauldin-Kinney for your help in proofreading the thesis document.

I extend my never-ending appreciation to my first love, honey buea and lovely husband, you are the best and indeed all that I want. Thanks to my precious children for their patience and understanding.

Special thanks to my late mother for her prayers through it all. I love and miss you so much. To my siblings, In-laws and friends, you all are a special support and pillar of grace always.

Thank you Federico, Kingsley, Esmel, Hilal, Adebayo, Dicson and Joe Hurley for your help.

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LIST OF ABBREVIATIONS

Al_2O_3	Aluminum oxide
CaO	Calcium oxide
Fe_2O_2	Iron oxide
K	Kaolinite
Rb	Rubidium
Sr	Strontium
Y	Yttrium
Zr	Zirconium
Nb	Niobium
XRF	X-Ray Fluorescence
XRD	X-Ray Diffraction
Q	Quartz
M	Muscovite
MgO	Magnesium oxide
MnO	Manganese oxide
P_2O_5	Phosphorus
K_2O	Potassium oxide
SiO_2	Silicon dioxide
TiO_2	Titanium dioxide
Na_2O	Sodium oxide

1. INTRODUCTION

1.1 General statement

This work covers quartzite, sandstone, and sandy shale components of the Weisner Formation in northwest Georgia. Outcrops of the formation are sparse in the state of Georgia due to the lack of a continuous exposure of undisturbed rock (Butts et al 1948). This Weisner Formation is a clastic sequence approximately 2000 to 3000 thick. The primary rock type in this formation is quartz sandstone, while shale is a secondary rock type. Conglomerate is the other constituent of this formation. In places, sandstone is metamorphosed into a dense quartzite. The quartzite is very resistant to weathering and erosion, and is exposed at high Stratigraphic level.

1.2 Location and extent of the study area

The studied sedimentary rock units are located northeast of Cartersville, along the SR 20 spur at SR 20 off of I-75 at exit #290. The studied units are a part of the Cambrian Weisner Formation. The main access route is Highway 20 East from I-75N; this locality is shown on the map in Figure 1.

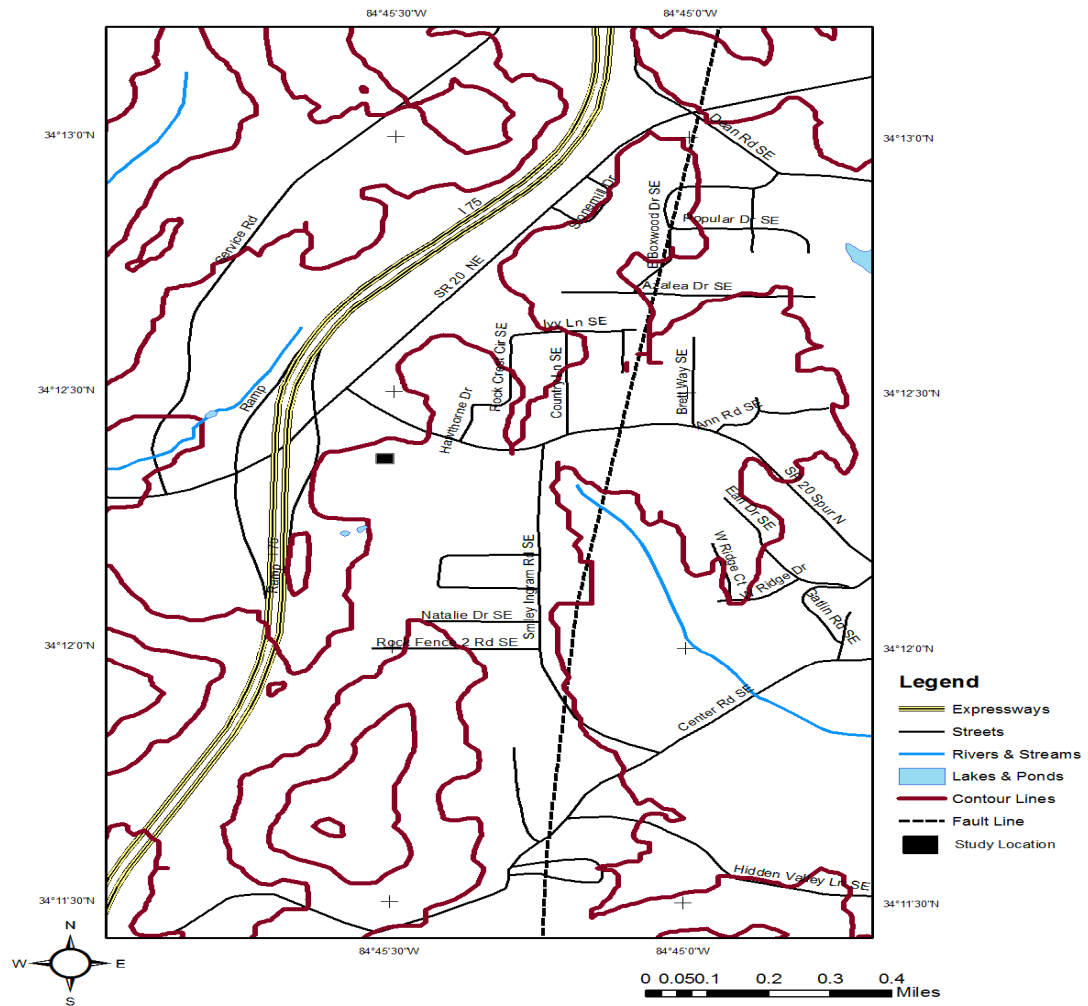


Figure 1: Location map of study area northeast Cartersville, Atlanta, GA.

*** Note the studied location shown as dark rectangle**

Source: Atlanta Regional Commission (ARC), Data 2011

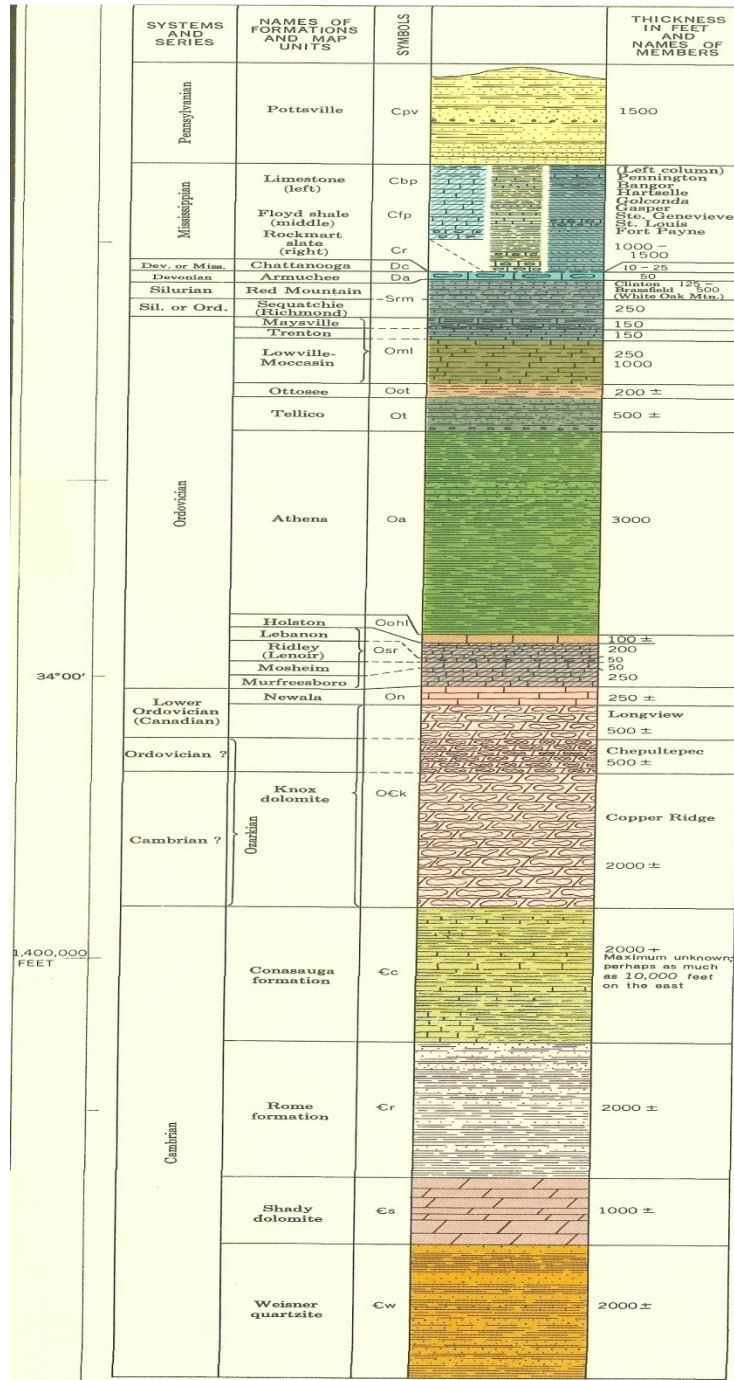


Figure 2: Stratigraphic Column of the Paleozoic rock in Georgia, (Butts, 1946)

Source: Geologic Map of Northwest Georgia

1.3 Previous Work

A small number of studies have been carried out on the Weisner Formation in the vicinity of Georgia. Butts et al., (1948) studied the Weisner Formation from western Polk County of the Indian Mountain area from Alabama into Georgia. He described the Weisner Formation as a unit containing thick beds of hard quartz sandstone and conglomerate interspersed with beds of shale. Kelser (1950) described the Weisner Formation as a unit of unknown thickness, and classified fresh quartzite as dark gray and fine-grained and light gray to white for the mostly weathered quartzite. The Weisner Formation consists of mostly angular quartz grains which is similar to the quartz grains in the sandstone within the study area.

1.4 Objectives of the present work

The objective of this study is to investigate the sedimentology and the paleoenvironment of the Weisner Formation. Additionally, we aim to classify the sandstone type and determine the basic mineralogy in different facies of this formation. An additional objective is to determine if the Weisner Formation is suitable for carbon sequestration by studying the relationship between the mineral grains and porosity of the sandstone. The paleoenvironment is determined from the grain size composition and sedimentary structures (such as parallel lamination, cross stratification, paleocurrent indicator, conglomerate and shale facies).

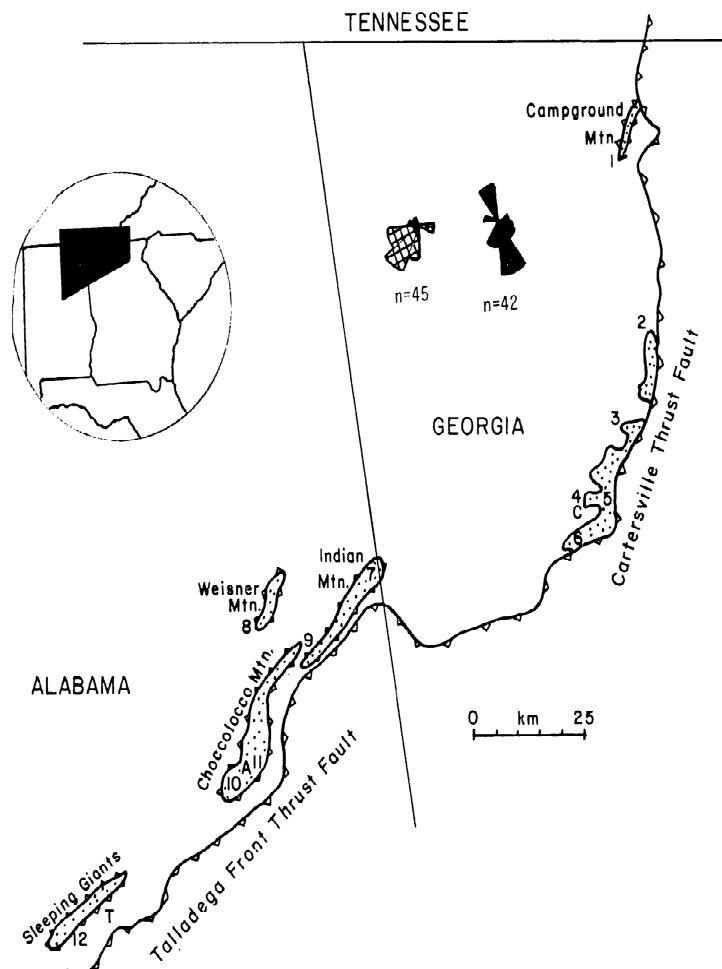


Figure 3: Index map showing the distribution of exposures of the Chilhowee Group in Georgia and Alabama, Cross bed paleocurrent roses are shown in 30° interval, for the Wilson Ridge Formation (dark) and Weisner Formation (cross hatched); n refers to the total number of cross bed reading in each Formation (After Mack, 1980)

1.5 Background Information

1.5.1 Geology of the study area

The Cambrian-aged rocks in the vicinity of Cartersville, Georgia consist mainly of sandstone, quartzite, conglomerate, shale, slate, schist, dolomites, marble, and limestone (Butts et al., 1948). The name Weisner quartzite is derived from the nearby Weisner Mountains in Cherokee County in Alabama by Hayes in 1901, But Mack (1980) refers to the Weisner quartzite as Weisner Formation. The Weisner Formation is the lower formation in the Cambrian rock and the oldest Stratigraphic unit of Paleozoic age in both Georgia and Alabama which is overlain by the Shady dolomite within the Appalachian Ridge and Valley province.

Outcrops of the Weisner Formation are common in Alabama, but are scarce in Georgia due to the lack of exposure of undisturbed beds. The Weisner Formation is more resistant to weathering compared to other rock types in this formation. This is due to the hard and dense nature of the rock caused by high heat and pressure during metamorphism that generated compact and tightly intergrown quartz crystals, (Butts et al., 1948).

Most of the rocks of Cambrian age in Georgia and Alabama are folded and faulted, causing elongated mountain such as the Lookout Mountain which span through three states, Alabama, Georgia and Tennessee. Nearly all the folds are strongly compressed; this is as a result of the flooding of the eastern North America by the ancient Iapetus ocean. The thickness of the Weisner Formation has not been accurately determined in Georgia. Hayes (1901) estimates the thickness between 2000 and 3000 feet. Butts et al., (1948) suggested a thickness of about 1,700 feet for the Weisner Formation in Georgia comparing it with the thickness of the Weisner Formation in

Shelby County, Columbiana Mountain, Alabama with 1,700feet thickness and have the same composition.

No fossil is observed in the Weisner Formation in Georgia (Kesler, 1950). Bedding is produced by a change in the grain size or composition of the particles being deposited, or by a pause during deposition. The main sedimentary features found in the Weisner Formation both in Georgia and Alabama are ripple marks, cross beds, paleo-current indicator, conglomerate. Fine grained clastic rocks such as mudstone are rare and in the Weisner Formation (Mack, 1980).

Cross stratification is common in the sandstone units exposed at the study area. The cross beds are non-horizontal, comprised of a series of thin, inclined layers within a large bed of sandstone. The cross beds formed when the layer and lamination that makes up the internal structure of the beds were deposited at an angle to the boundary of the bed. This structure is found in the sandstone facies of the study area. Parallel lamination is observed within the sandy shale, and consist of sedimentary units (laminations) less than 1.2 centimeters thick. The laminations are differentiated from beds by their smaller thickness, by being confined within beds and by not having thinner, visible sedimentary layer. Such structures are representative of bed forms such as dunes or ripples (Boggs, 2006)

1.5.2 Facies

The Weisner Formation has two main facies, sandstone facies and the shaly facies. Facies can be described in term of sediment, for example a cross bedded sandstone facies, or by using lithology. We can also define a facies in term of depositional process, for example a fluvial facies or shallow water facies. Sedimentary facies is a mass of rock which can be defined and distinguished from others by geometry, lithology, sedimentary structure, paleocurrent patterns,

and fossils. The relationship between facies and environment was first noted by Walther in 1894, and this relationship was adopted as Walther's Law of facies which states that "As depositional environments migrate laterally, the sediment of one environment come to lie on top of sediment of the adjacent environment" (Walther, 1894). This implies that a conformable vertical sequence of facies is generated by a lateral sequence of environment, for example a prograding delta produces differences in the facies from variation in depositional processes.

Paleo-environmental Interpretation is improved when we study "facies association" (groups of facies that occur together and genetically related), for example if cross bedded sandstones occurs in association with peat, coal or silty shale we may infer a river system. Vertical succession or lateral variation of facies offers much information for environmental interpretation. There are two types of facies changes; fining upward sequences are associated with fluvial systems while Coarsening upward is associated with beaches and a deltaic system, which is the most likely interpretation of the study area (see below).

The facies observed in the study area have different mineralogy and chemistry. The mineralogical composition and textural relationships within the sandstone facies varies little. The sandstone is classified as quartzite, more than 90% of the grains are quartz, and since quartz is stable through chemical weathering, it tends to concentrate residual in sand, while the less resistant minerals such as feldspars are weathered away.

1.5.3 Potential of Weisner Formation sandstone for carbon sequestrations

The Weisner Formation sandstone is a highly porous rock, resulting from the good sorting of the grain size. All sample collected are well sorted indicating good porosity, hence a good reservoir potential. For rocks to be considered as a reservoir rock for the storage of a fluid or

CO₂ they must have the ability to hold and store CO₂ without leakage or escape for a long period of time. The spill or leakage of a natural storage has been restricted to fracture and faults, rather than chemical alteration of porosity in reservoir rocks (Alemu et al., 2011)

Most of the Weisner Formation rock occurs with a cap rock (Huckins et al., 2012). The Weisner Formation sandstone is found to be overlain by sandy shale which is considered to be clay-rich shale consisting of mainly clays, quartz and some mica content. The clay content is dominated by kaolinite. This clay-rich shale is considered to be a cap rock because it is impermeable and forms a seal above or around the reservoir rock, preventing the escape or leakage of CO₂ beyond the reservoir.

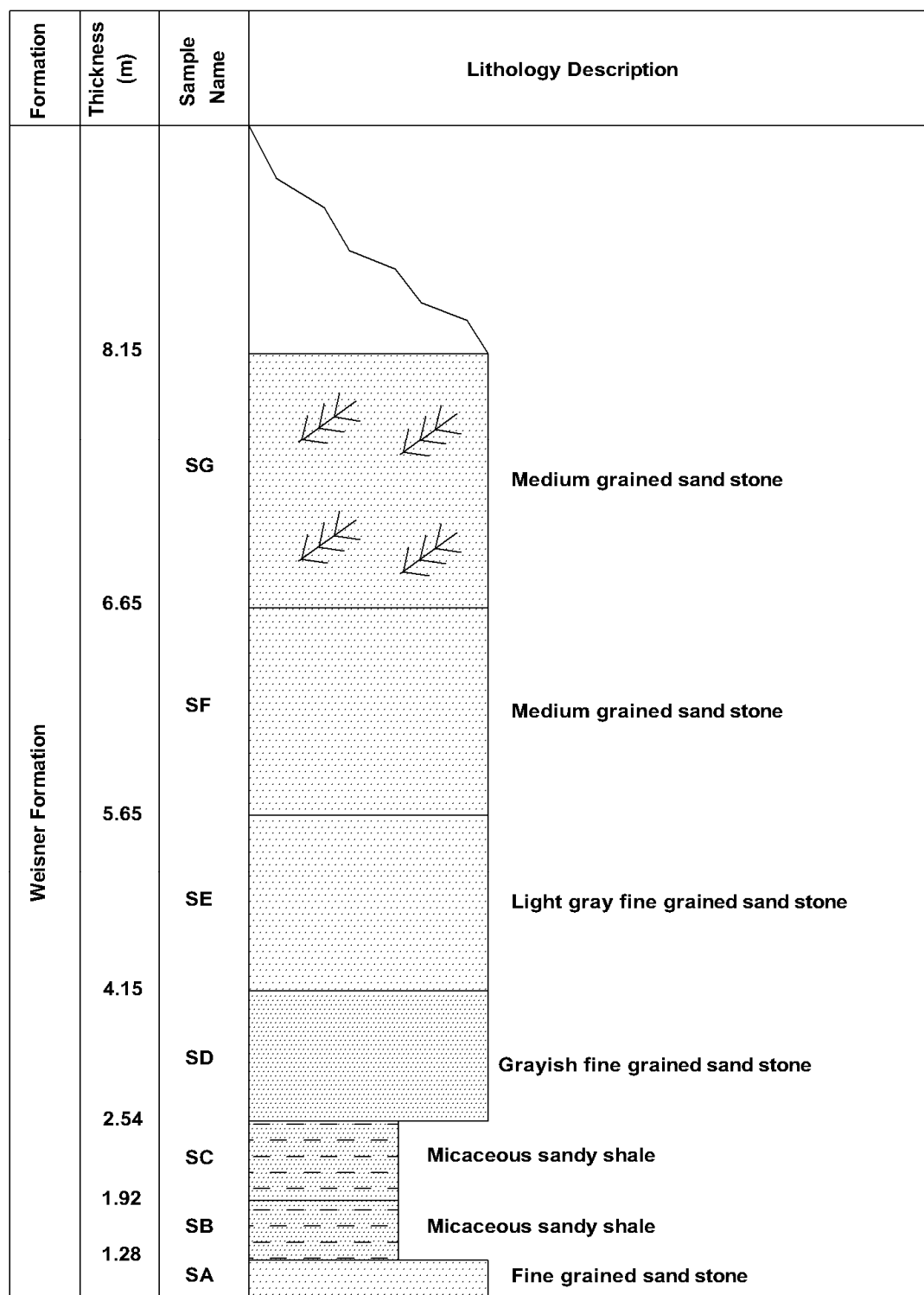


Figure 4: Summary Stratigraphic column of Weisner Formation from Bartow County, Northeast of Cartersville, Georgia.

2. METHODS

The work involved both fieldwork and laboratory analyses including thin section microscopy, X-ray Diffraction (XRD) and X-ray Fluorescence (XRF).

2.1 Field mapping and sample collection

The field mapping was carried out on November 9, 2011 in the area where the Weisner Formation is exposed along Highway 20, east of Cartersville in northwest Georgia. Physical characteristics of the rock such as color, grain size, mineral composition, lithology, and lithogacies were described. Representative samples were collected from the outcrop with the direction of Dr. Deocampo. Each sample was stored in a plastic bag and labeled. Sedimentary structures within the outcrop were also described and recorded. Attitude measurements (strike and dip) were taken at the outcrop for further analysis.

2.2 Sample Preparation

The laboratory studies carried out at Georgia State University Geosciences Department included XRF and XRD. Thin sections were made commercially by Spectrum Petrographic, Inc.

2.2.1 Thin Section Preparation

The thin sections were prepared from the samples using the procedures describe below, (done by Spectrum Petrography, Inc). A total of seven (7) sandstone samples of the Weisner Formation were selected for this Petrographic analysis. The weakly consolidated sandstone was first impregnated with Canada Basalm and Lakeside 70 Cement in the same proportion and heated in hot flame for a period of 30 minutes before thinning. The surface was smoothed with

Carborandum grit grading from 90 (coarse) to grade 400 (fine). Glass slides were then labeled and the samples mounted on them using araldite epoxy as adhesive, ensuring the mount was bubble free. The samples were then heated on the electric dryer and left to cool in room temperature air. The mounted samples were then sufficiently reduced with a reducing wheel to ease finishing. Finishing was first carried out with Carborandum grit grade 400 and finally with fine grade 800.

During finishing, the petrologic microscope was used to monitor the change in color to the required birefringence; this is also to ensure that the samples were not completely washed off the side. At this stage the slides were washed with water and left to dry.

2.2.2 X-Ray Fluorescence (XRF) analysis

Samples were prepared following the Method of Latour (1989). Each representative samples collected in the field was broken down in to small pieces using a rock hammer and then crushed in to powder form using the SPEX Shatter box. Each crushed sample was poured into a plastic bag and labeled respectively. Precautions were taken to avoid contamination of each sample. These powdered samples were used for both XRF and XRD analyses. Seven samples were collected from the Weisner Formation was fused using lithium tetra borate fusion. One-half gram (0.5 g) of each of the samples was weighed and mixed with 4.5 g of the flux, which was gently swirled for proper mixing of the sample and the flux.

The mixture of each sample was placed in a platinum crucible and then placed in the furnace at 1100 °C for 10 minutes, which turned the sample mixture into a liquid form. The mixture in the crucible was swirled over blast burner for a few minutes to remove air bubbles and then place back into the furnace for an additional five minutes. The liquid was then poured into a

mold and allowed to harden. It was then removed from the mold, allowed to cool, and numbered to correspond to the actual sample. Precaution was taken to make sure the mixture was not contaminated from previous sample by washing the platinum crucible before pouring the mixture of another sample. Finally X-Ray Fluorescence (XRF) instrument was used to analyze the sample for their major element.

2.2.3 X-Ray Diffraction (XRD)

All selected sandstone samples were crushed into powder form and were analyzed using the Panalytical XPERT PRO MPD X-ray diffractometer at Georgia State University, Department of Geosciences with $CuK\alpha$ radiation. The samples were randomly mounted in an aluminum specimen holder. Scanning started at 5.0 degree 2θ to 65.0 degree 2θ Scans were continuous with a .01 step size, and X-rays were generated at 40mA and 45KV.

Mineral Identification and analysis from the diffraction pattern was generated using Data Collector to measure the d-spacing and High Score Plus Program to identify the minerals by using the search-match function, which compared the peaks in the sample diffraction pattern to a database of minerals.

3. RESULTS

3.1 Lithological description of the outcrop

The exposed outcrop of the Weisner Formation is predominantly quartz sandstone. The section has a total thickness of approximately 31 meter thick. The lithologic units observed at this section have different characteristics and features which distinguish them from one another. The basal lithologic unit is quartz sandstone with a reddish/milky white color with some mica content, and is overlain by sandy shale (possibly representing a delta deposit). There is no sharp contact between the sandy shale and the quartz sandstone. The sandy shale is milky-white to gray, and is micaceous. Fault cutting the sandstone, may have served as pathways for hydrothermal alteration.

Some of the rock units are recrystallized and highly weathered. The rock unit has no regular stratigraphic order. The Interpretation of an ancient depositional environment of rock or sediment in terms of the environment condition that prevailed at or shortly after deposition is based on the ability to identify, describe, and interpret the environmental significance of some certain feature and structures which are the imprint of these conditions preserved in the rock sediment.

Sedimentary structures present useful tools in the reconstruction of the paleoenvironment. The internal megascopic feature of the sediment can be defined as sedimentary structures. Figures 4 and 5 shows a fault on the outcrop of the study area.



Figure 5: Picture showing a fault plane on the outcrop.



Figure 6: Picture of the outcrop showing shale facies overlain by the sandstone facies.

3.2 Sample Description

Seven samples, SA, SB, SC, SD, SE, SF, and SG were collected from different varieties of the rock. The sandstones are mostly well-or moderately-sorted, and are very fine to coarse-grained. Quartz is the major clastic component in all the samples, and constitutes between 65% and 98% of the rock.

Sample SA is milky white and very compact and hard. Grains are dominantly of clay size with some sand, which are well-sorted and sub-angular in shape.

Sample SB is milky white fissile (splits easily into layers), shale with clay sized grains, which are well-sorted and sub-angular in shape. Grains are mostly clay and quartz.

Sample SC is milky fissile, well-sorted shale. The grains are mostly clay and quartz.

Sample SD is grayish sandstone with muscovite. The rock has brown stains (possibly iron oxide), with moderately sorted and sub-angular grains of mostly sand and gravel.

Sample SE is taken from a light gray and white sandstone. Grains in this sample are sub-angular, moderately sorted, and are of sand and gravel size. The grains are quartz, micas and iron oxide. This sample is distinctive in that it is metamorphosed sandstone (quartzite).with recrystallized quartz grains.

Sample SF is dominated by gravel sized grains with some sand. It is moderately sorted, and is composed of mostly quartz, and grayish minerals, mostly mica and some iron oxides. The mineral composition is mostly tightly interlocking grains of quartz.

Sample SG contains mostly sand-sizes grains with some gravel, and is moderately sorted, mostly quartz, grayish mica, and red Iron oxide. The mineral composition is of tightly interlocking grains of quartz.



Figure 7: Photography of representative samples collected on field.

3.3 Petrography

Petrographic study of the seven selected sandstone samples from the Weisner Formation (Quartzite) in Carterville (SA, SB, SC, SD, SE, SF, SG) show varying proportion of minerals (Table 1). The mineralogy of sandstone and shale sample was done by point counting. The minerals in the studied sandstone are mainly quartz, feldspar, and muscovite. Quartz is the main component, ranging from 80%-90% in all sandstone samples (Table 1). 1% of feldspar is observed, while muscovite constitutes 1% to 30% of the sample.

Lithic (rock) fragments are few and the matrix is composed of abundant clay particles. This clay matrix fills part of the intergranular voids acting as subordinate cement (binder to other minerals grains). The quartz grains range from angular to sub-angular. This implies that the sandstones were probably deposited close to the source rock.

Most of the quartz grains observed goes into extinction at 90 degrees on rotation of the stage. The quartz and feldspar show significant number of fractures and size reduction. The type of quartz grains observed in the entire sandstone sample is monocrystalline rocks.

The abundance of monocrystalline quartz is indicative of sediment derived either from volcanic-plutonic rocks or pre-existing sedimentary rocks. Most of the minerals were extensively mechanically weathered. The shale sample shows a high percentage of micas, mostly muscovite, which signifies chemical weathering through hydrolysis. Minor amounts of Iron-oxide were observed (in the form of hematite) which acts as the cementing mineral. See Table 1 for the framework grains found in thin sections.

Table 1: Frame work grains found in thin sections

Location	Formation	Sample Name	Quartz(%)	Feldspar(%)	Muscovite(%)	Shape
Cartersville	Weisner	SA1	97	0	3	Sub-angular
Cartersville	Weisner	SA2	97	0	3	Sub-angular
Cartersville	Weisner	SB1	79	1	20	Sub-angular
Cartersville	Weisner	SB2	79	1	20	Sub-angular
Cartersville	Weisner	SC1	69	1	30	Sub-angular
Cartersville	Weisner	SC2	69	1	30	Sub-angular
Cartersville	Weisner	SD1	97	0	3	Sub-angular
Cartersville	Weisner	SD2	97	0	3	Sub-angular
Cartersville	Weisner	SE1	90	0	10	Sub-angular
Cartersville	Weisner	SE2	90	0	10	Sub-angular
Cartersville	Weisner	SF1	96	0	4	Angular
Cartersville	Weisner	SF2	96	0	4	Angular
Cartersville	Weisner	SG1	99	0	1	Sub-angular
Cartersville	Weisner	SG2	99	0	1	Sub-angular

3.4 Diagenesis

Diagenesis refers to the state of sediment burial, it occurs at a high temperature and pressures compared to those in the weathering environment but below the condition that produce regional metamorphism. It is inferred from the textural properties of minerals and based on the nature of the contact and packing of the grains. There are main types of mineral contacts: point contact, long contact, sutured contact and concave-convex contact, the sutured point contact ap-

appears as a wavy line in the plane of a thin-section and the long point contact appears as a straight line in the plane of a thin-section. (Boggs, 2006).

When mineral constituents are loosely packed, it implies an early stage of diagenesis and when mineral constituent are closely packed, it implies a late stage of diagenesis. The mineral constituents within the sandstone facies of the Weisner Formation are loosely packed which suggests an early stage of a shallow-burial diagenesis of the sandstone facies of the Weisner Formation. Figure 8 and 9 are compacted by both long point and sutured contact indicating advanced degree of diagenesis, which reduce porosity in sandstone.

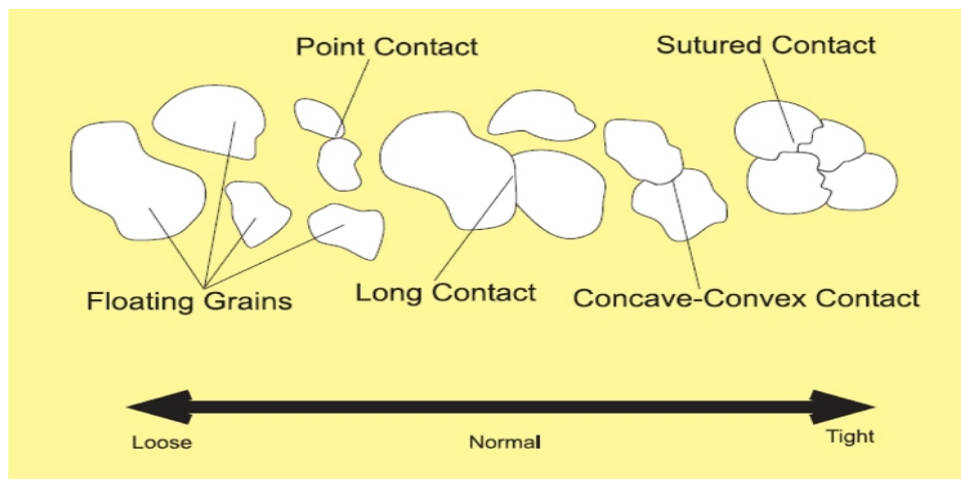


Figure 8: Grain contact type influenced by rock packing.

Source: <http://www.searchanddiscovery.com/documents/2009/80061santin/images/fig02.htm>

3.5 Porosity

Porosity is a measure of the ratio of the total volume of void space (pore space) to the total volume of sediment or rock. There are two types of porosity: primary and secondary, primary porosity is the main porosity in the rock system while the secondary porosity forms subsequent to the formation of the rocks and may be caused by leaching away of other minerals or fracturing.

Primary porosity in sandstone is defined by interstitial voids and is dependent on textural maturity of the sediments. The textural maturity refers to the sorting and packing of the particles. In well-sorted sandstones there is good porosity while in poorly-sorted there is poor porosity. The mineral constituents of the seven selected samples from the study area are mostly moderately- to well-sorted, indicating good porosity, and thus good reservoir characteristics of the sandstone facies within the Weisner Formation. Some secondary porosity is probably due to the dissolution and the leaching of feldspar grains

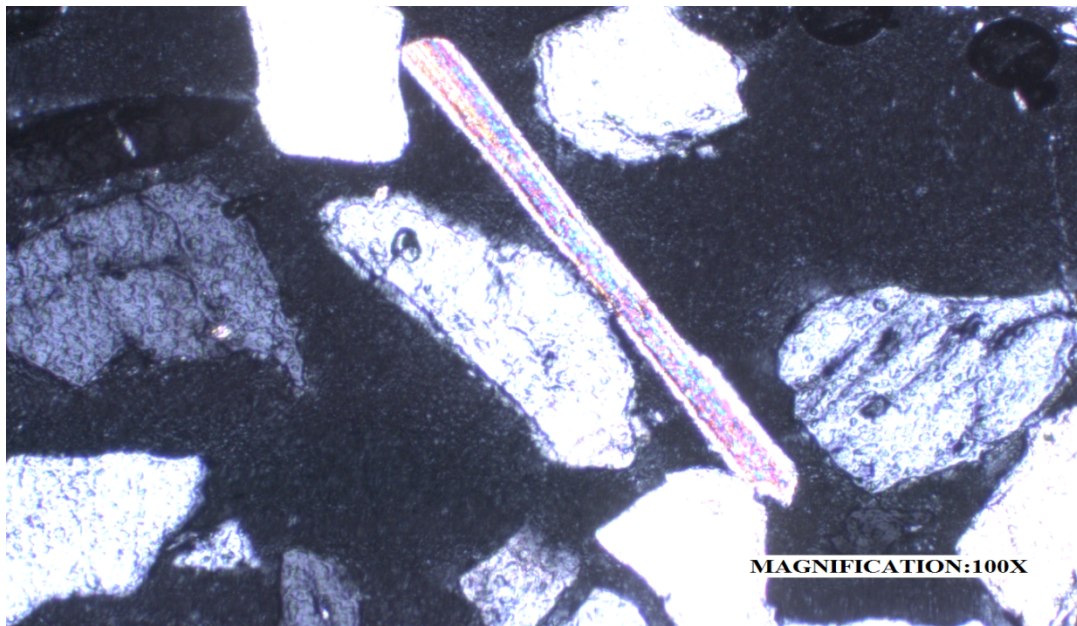


Figure 9: Photomicrograph of sandstone sample C2 showing fractured quartz and mica, (Crossed polars).

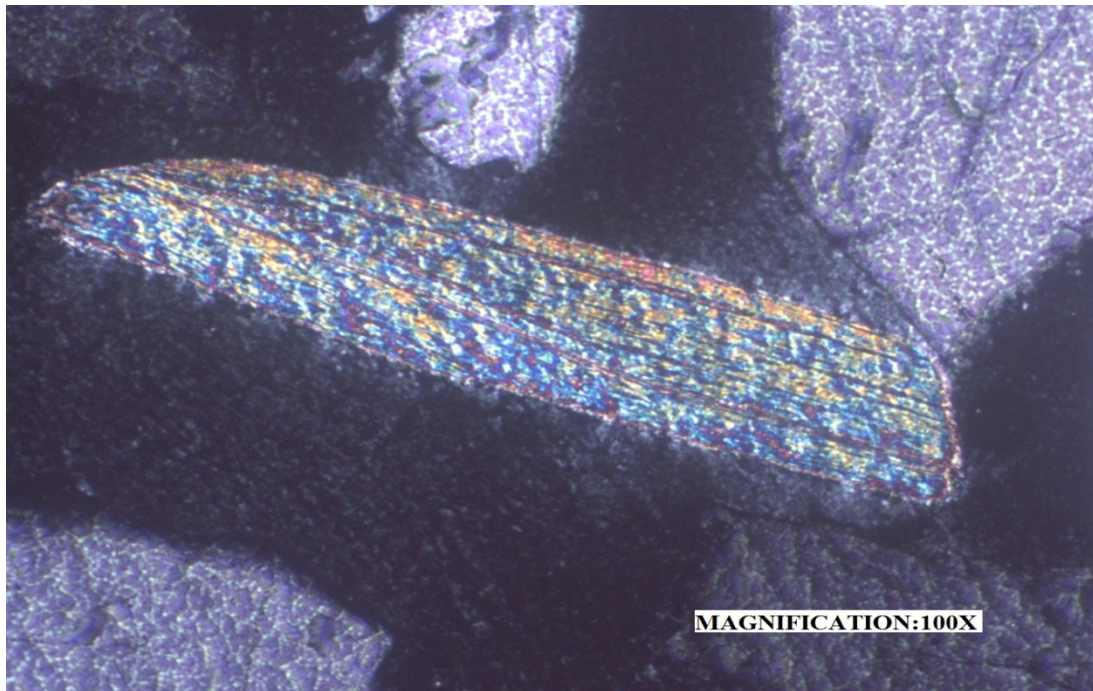


Figure 10: Photomicrograph of shale sample C2 showing mica with round (crossed polars).

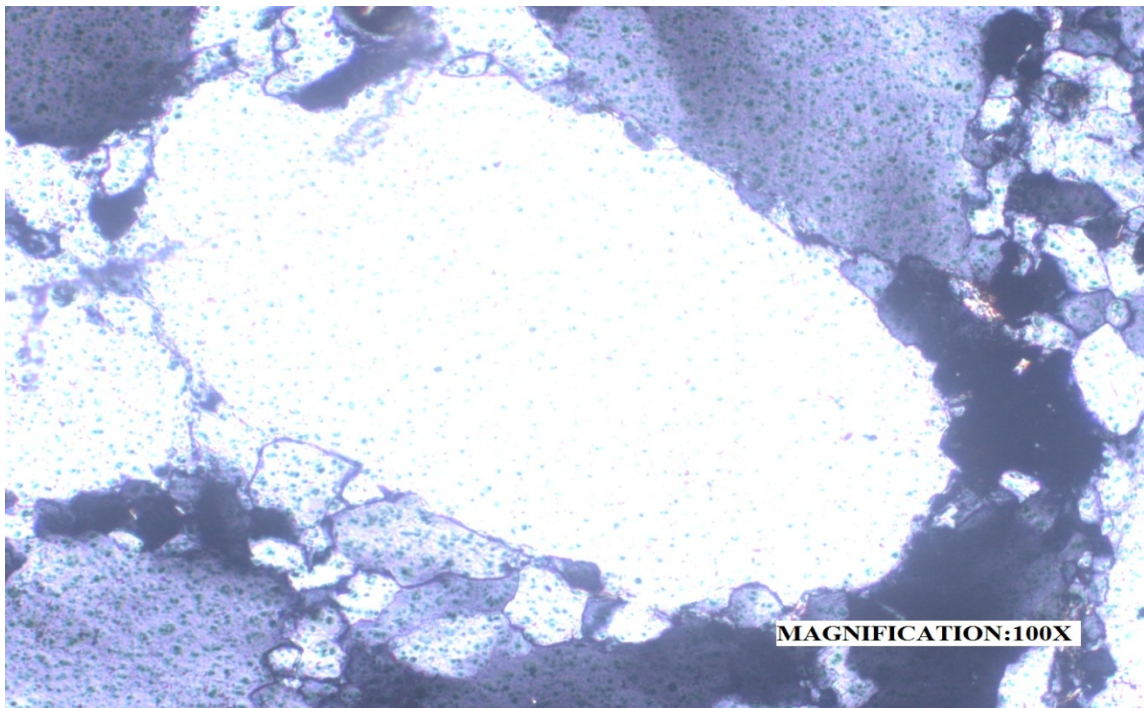


Figure 11: Photomicrograph of sandstone sample G showing some stained quartz (Crossed polars).

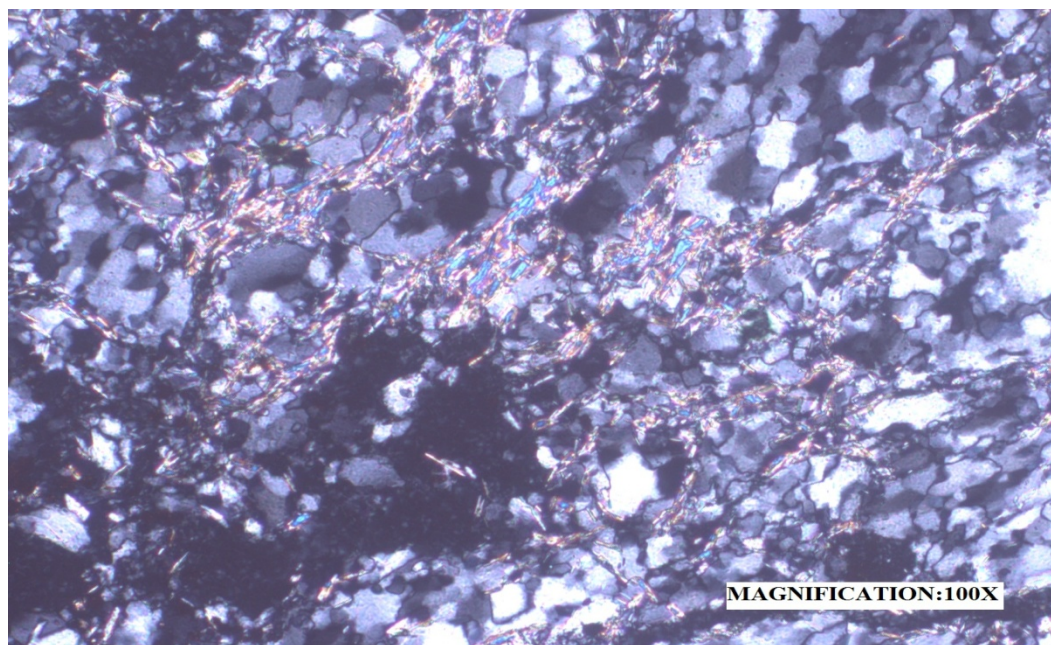


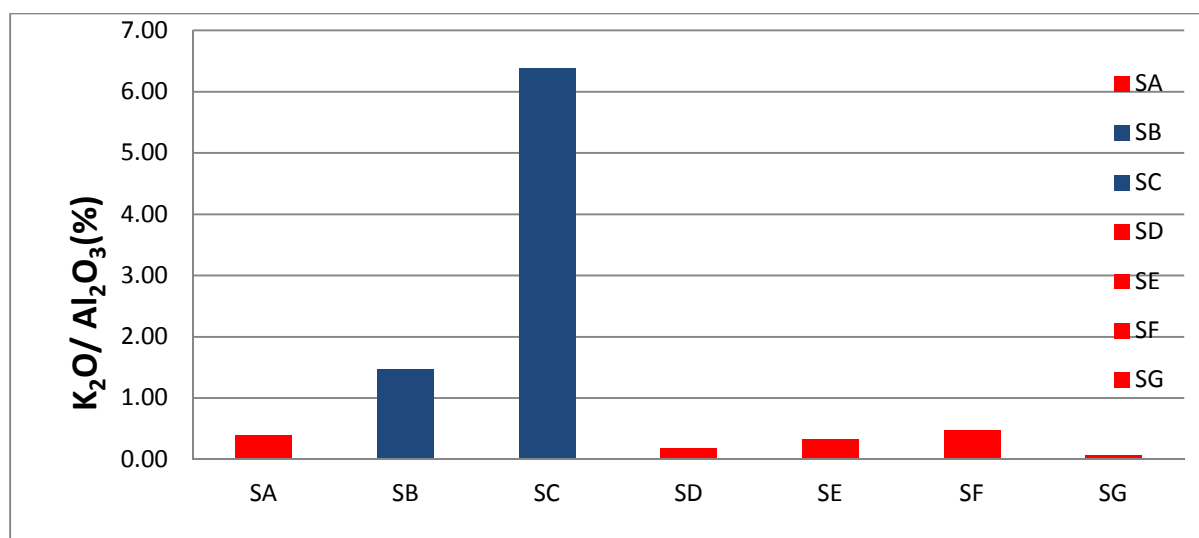
Figure 12: Photomicrograph of shale sample B1 showing abundant micas (crossed polars).

3.6 Major Element Data From XRF

A total of seven samples were analyzed for chemical composition. Table 2 shows the major element data for the sandstone and shale samples of Weisner Formation collected from the study area. The sandstone has the highest percentage of SiO_2 which range from >97 to 100wt. % while SiO_2 of the shale sample ranges from 60.80 to >97wt. %. The TiO_2 content is high in the shale samples compare to that of sandstone, ranges from 0.05 to 0.29wt. %. The Fe_2O_3 content in the shale sample range from 1.42 to 6.38 wt. % while in the sandstone the Fe_2O_3 content is less than 1wt.%. MgO content in the shale sample range from 0 to 0.19wt. %, but not detected in the sandstone sample. MnO , CaO , P_2O_5 are less than 1wt. % in all of the samples and Na_2O is not detected in any of the samples.

Table 2: Major element data from XRF analysis on Weisner sample

Sample	Source	Percentage Composition(Wt %)								K ₂ O	P ₂ O ₅	K ₂ O/Al ₂ O ₃	K ₂ O/TiO ₂
		SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Mno	Mgo	CaO	Na ₂ O				
SA	Cartersville	>97	0.29	1.76	0.47	0.00	N.D	0.00	N.D	0.39	0.03	0.22	1.34
SB	Cartersville	>97	0.48	4.78	1.42	0.00	0.19	0.01	N.D	1.47	0.03	0.31	3.06
SC	Cartersville	60.80	1.71	35.40	2.69	0.00	1.07	0.00	N.D	6.38	0.04	0.18	3.73
SD	Cartersville	>97	0.11	0.84	0.81	0.05	N.D	0.04	N.D	0.18	0.03	0.21	1.64
SE	Cartersville	91.77	0.08	1.40	0.37	0.00	N.D	0.02	N.D	0.32	0.03	0.23	4.00
SF	Cartersville	>97	0.18	1.68	0.87	0.00	N.D	0.02	N.D	0.48	0.02	0.29	2.67
SG	Cartersville	>97	0.05	0.49	0.90	0.00	N.D	0.03	N.D	0.06	0.03	0.12	1.20

**Figure 13: K₂O/Al₂O₃ ratios of the Weisner Formation sandstone and shaly facies samples.**

3.7 Trace element data from XRF

Table 3: Trace element data from XRF analysis on Weisner Formation samples (sandstone and shaly facies).

Sample	Source	(ppm)					
		Rb	Sr	Y	Zr	Nb	Rb/Zr
SA	Cartersville	11	11	16	389	6	0.0283
SB	Cartersville	31	12	33	641	9	0.0484
SC	Cartersville	172	2	101	624	25	0.2756
SD	Cartersville	9	3	3	67	8	0.1343
SE	Cartersville	6	2	2	53	1	0.1132
SF	Cartersville	8	5	7	145	7	0.0552
SG	Cartersville	5	5	1	26	5	0.1923

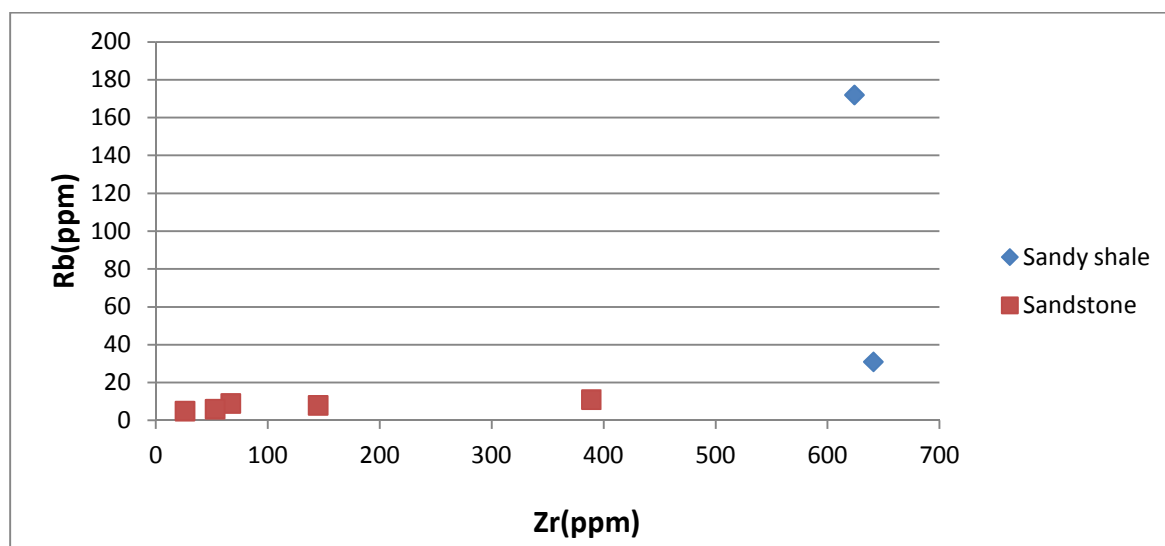


Figure 14: Scatter plot of rubidium (Rb) against Zirconium (Zr) for the Weisner Formation sandstone and shaly facies samples.

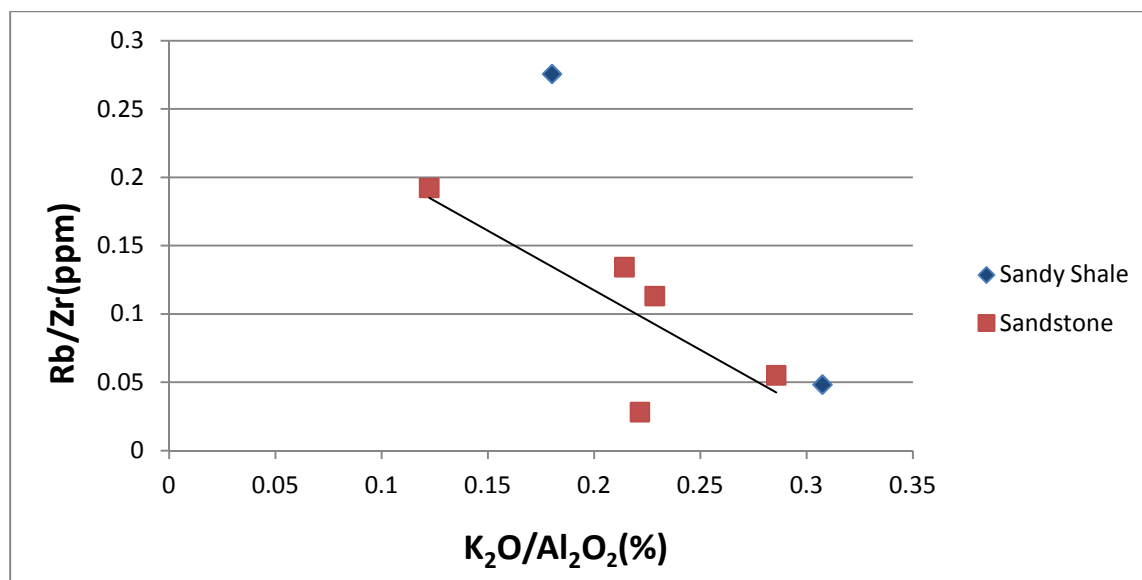


Figure 15: Scatter plot of (Rb/Zr) against (K₂O/Al₂O₃) for the Weisner Formation sandstone and shaly facies samples.

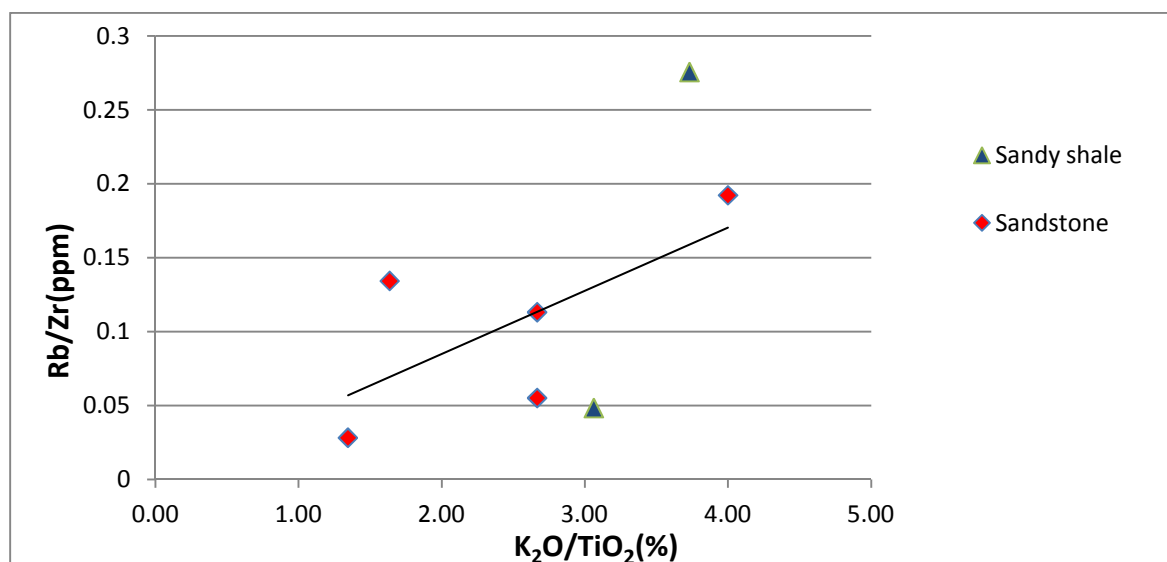


Figure 16: Scatter plot of (Rb/Zr) plotted against (K₂O/TiO₂) for the Weisner Formation sandstone and shaly facies samples.

3.8 Whole rock XRD analysis

Most of the samples analyzed are highly weathered sandstone, recrystallized sandstone and sandy shale. All of these samples were crushed and ground into a powdered form. All the sandstone samples consist of mostly quartz, the sandy shale consists of quartz, muscovite, and kaolinite. Figure 7 to Figure 14 show the XRD patterns for all the samples analyzed and Table 4 shows the summary of the XRD results of mineral composition.

Table 4: Summary of the XRD result of the mineral composition in the samples.

Sample SA	Sample SB	Sample SC	Sample SD	Sample SE	Sample SF	Sample SG
Quartz	quartz	quartz	quartz	quartz	quartz	quartz
muscovite	muscovite	muscovite				
		kaolinite				

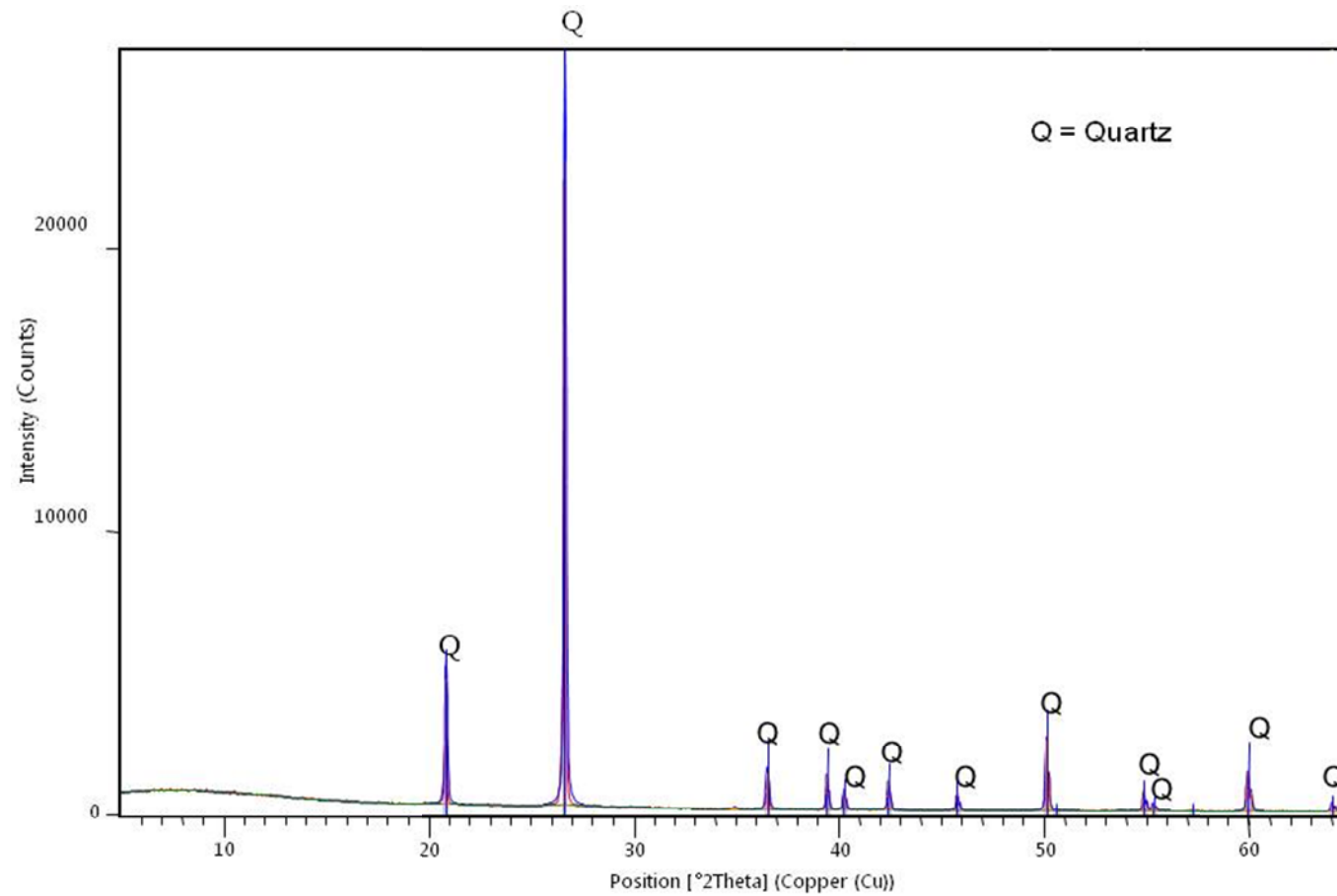


Figure 17 : X-ray diffraction pattern of Weisner Formation Sandstone (Sample SA)

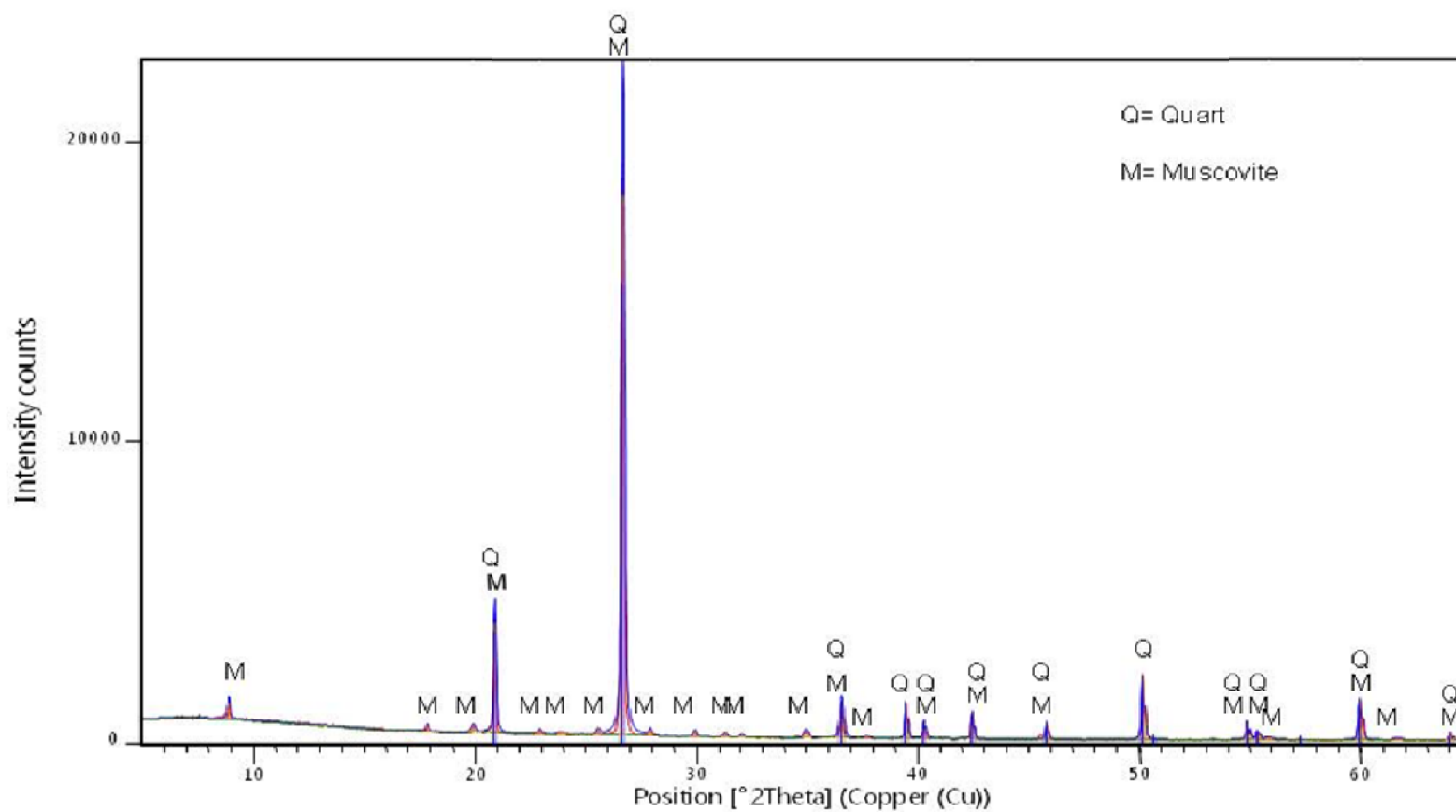


Figure 18 : X-ray diffraction pattern of Weisner Formation Sandy Shale (Sample SB)

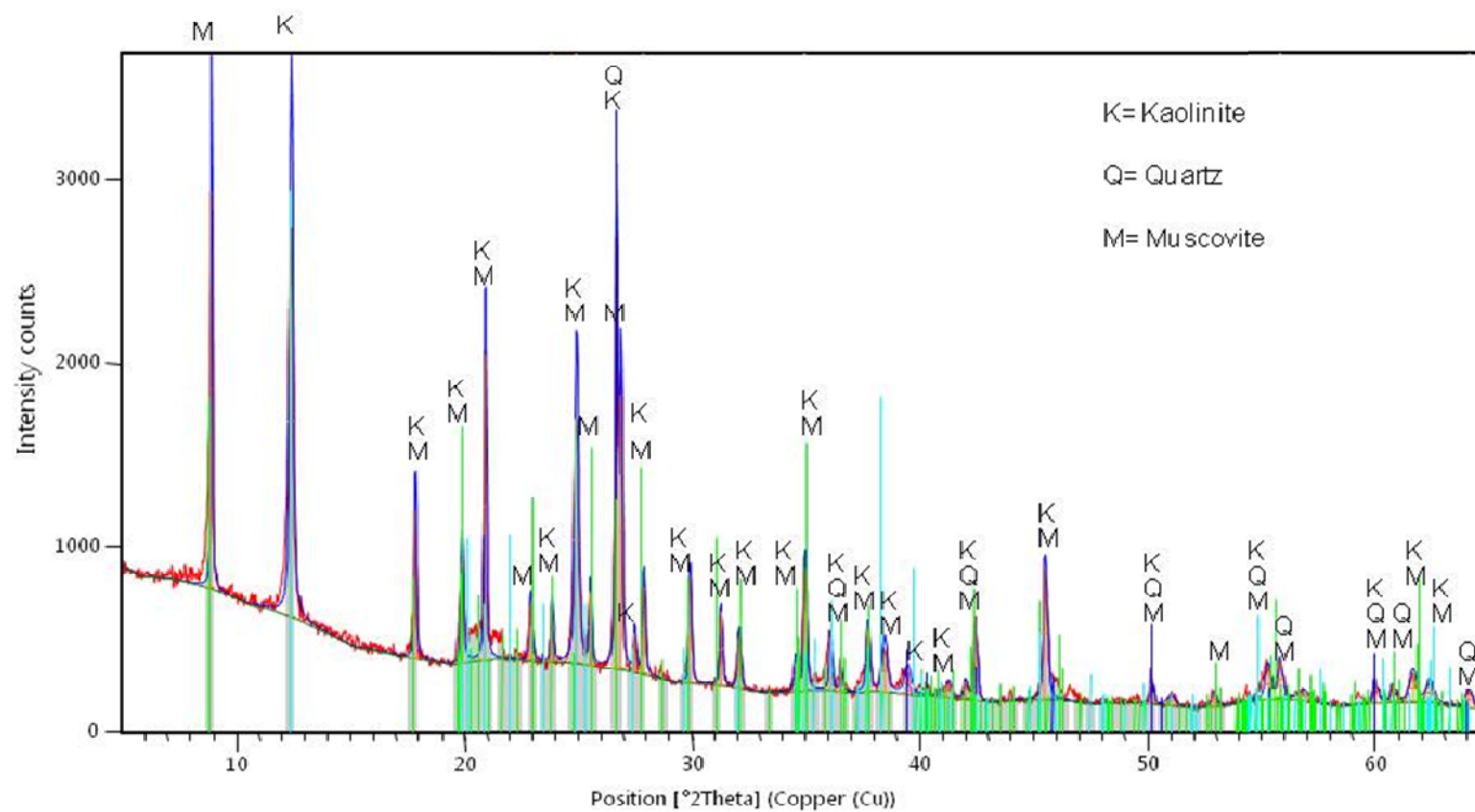


Figure 19 : X-ray diffraction pattern of Weisner Formation Sandy Shale (Sample SC)

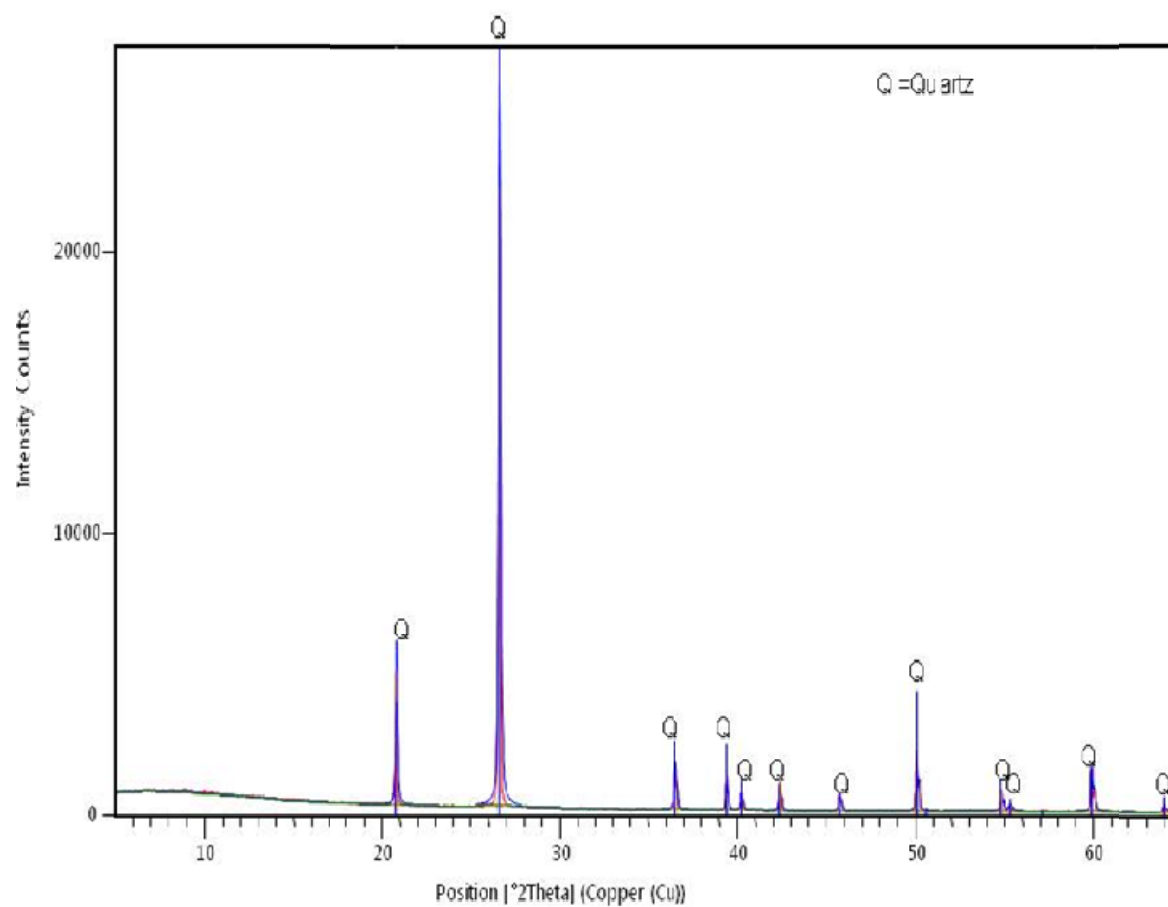


Figure 20 : X-ray diffraction pattern of Weisner Formation Sandstone (Sample SD)

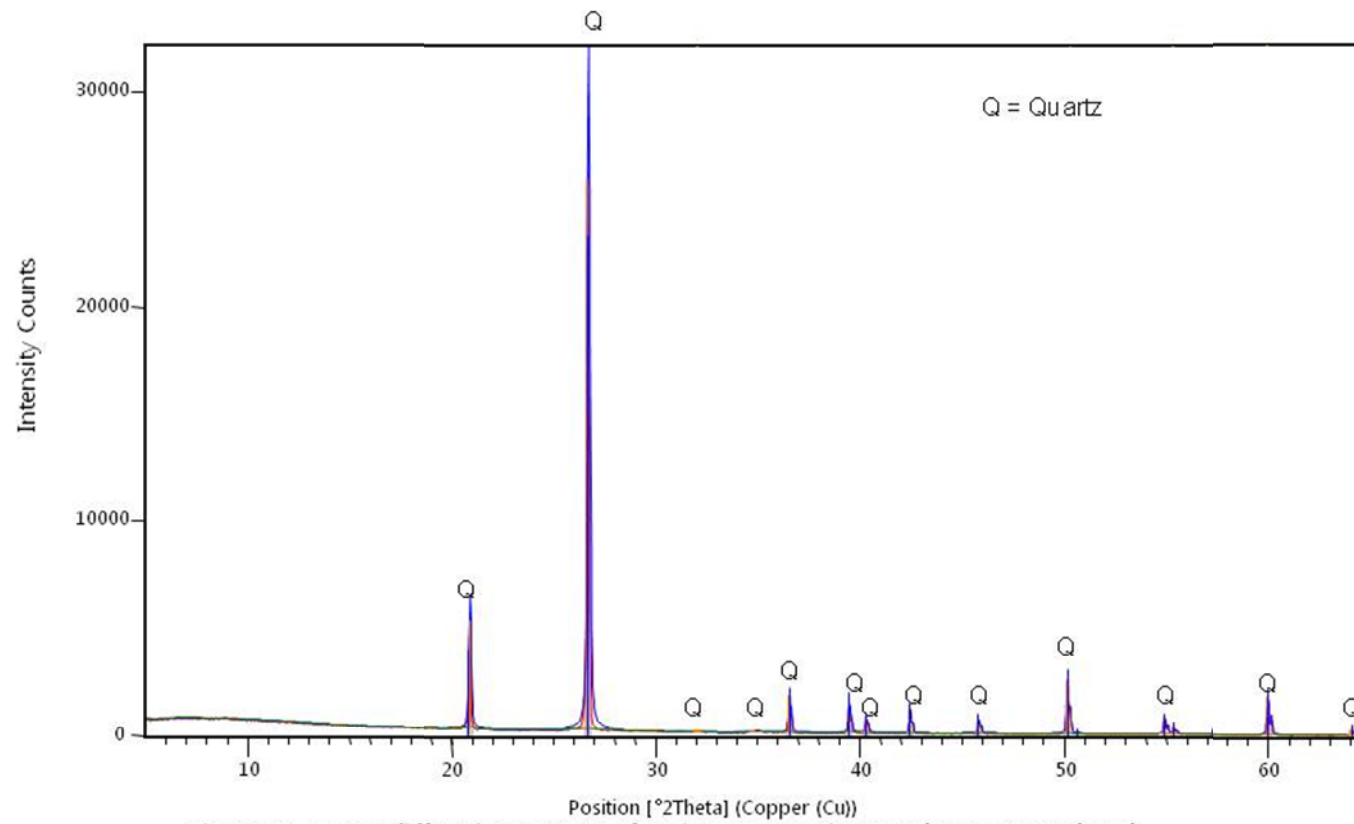


Figure 21 : X-ray diffraction pattern of Weisner Formation Sandstone (Sample SE)

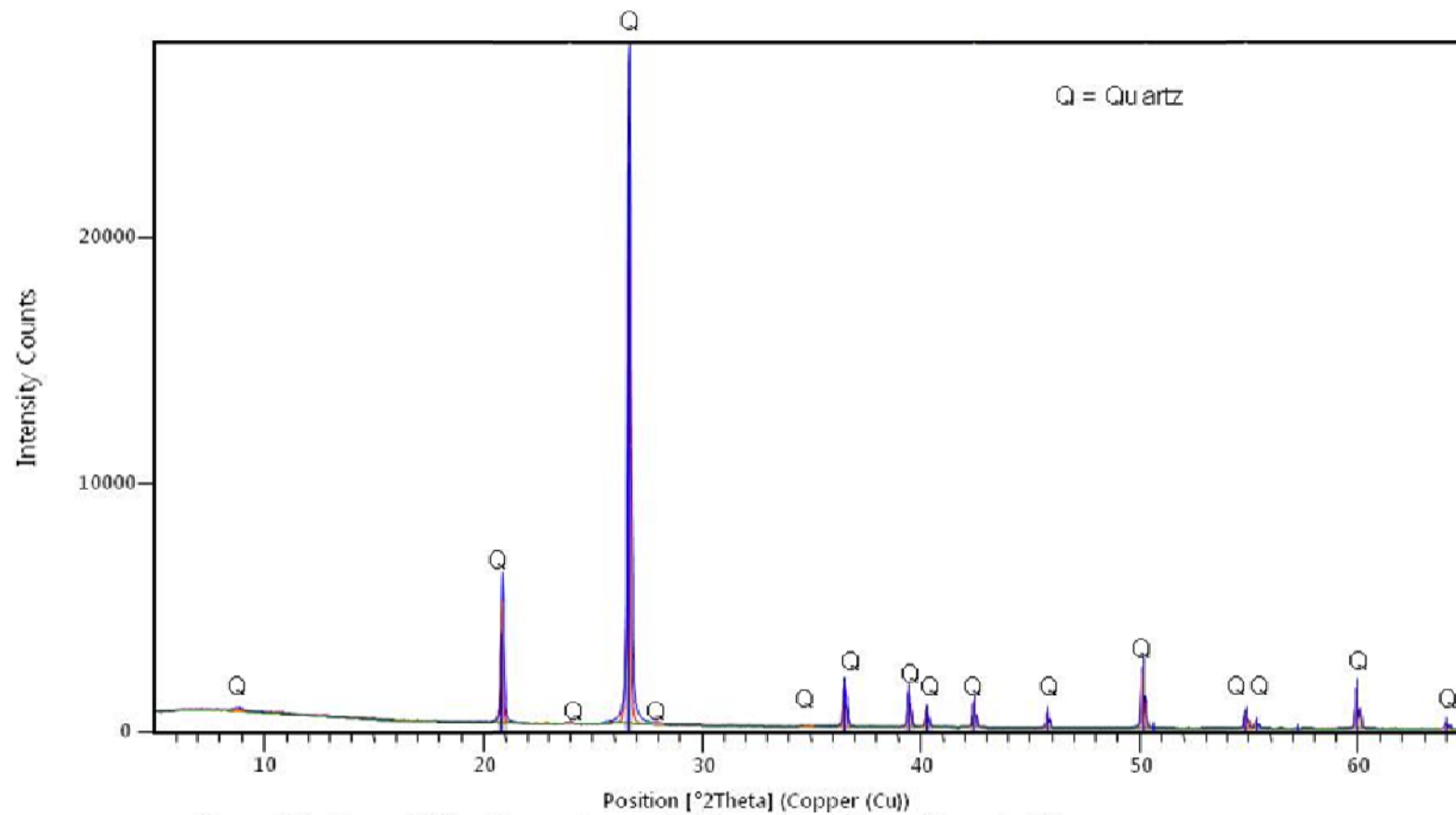


Figure 22 : X-ray diffraction pattern of Weisner Sandstone (Sample SF)

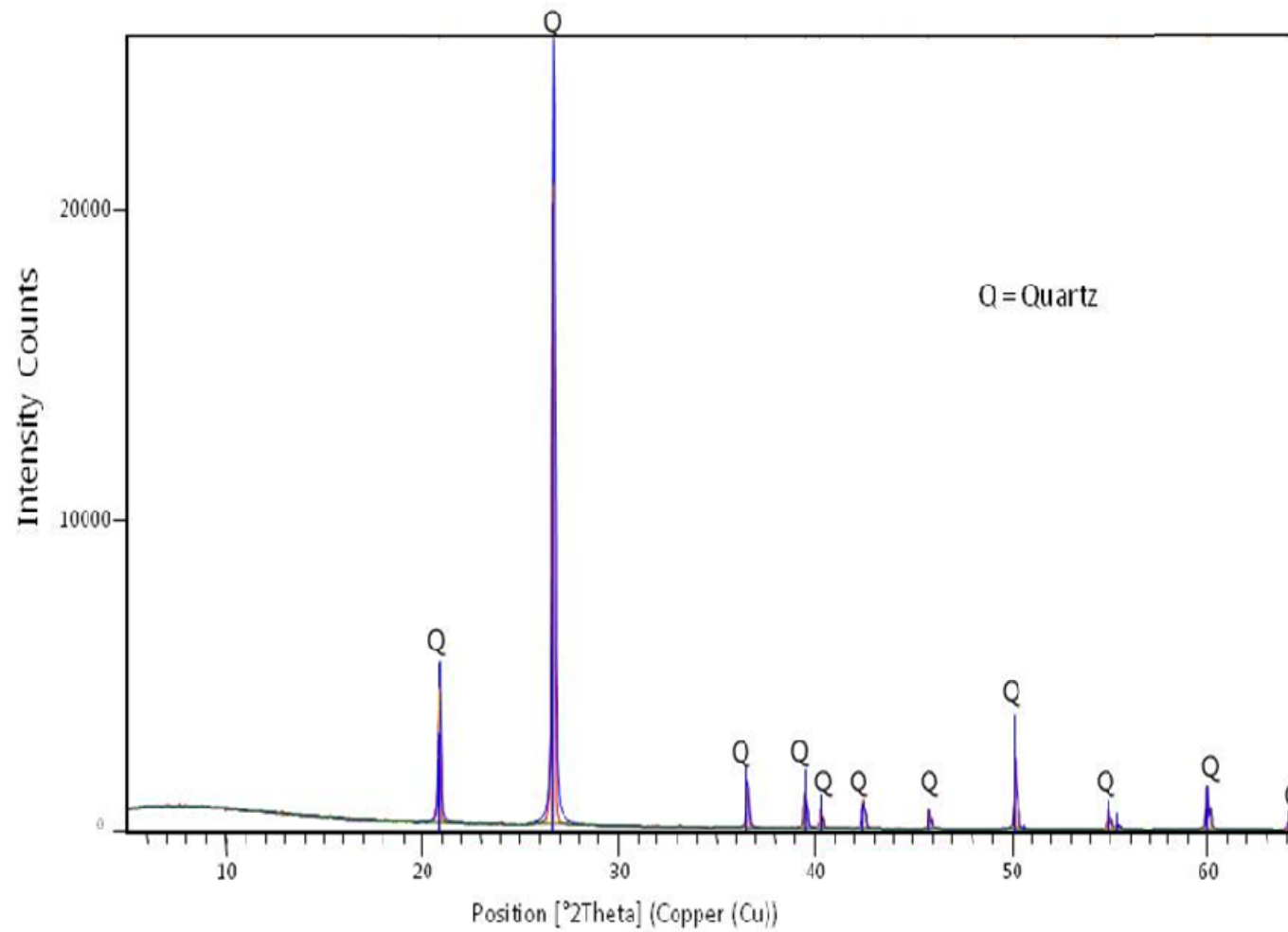


Figure 23 : X-ray diffraction pattern of Weisner Sandstone (Sample SG)

4. DISCUSSION

Quartz is the major mineral constituent of the Weisner Formation sandstone, with some unstable detrital minerals such as muscovite which make up an average of 5-10% of the rock. The abundant detrital minerals reduce the porosity in sandstone. Detrital grains are more abundant in the sandy shale sample, probably reducing the porosity even further. The quartz sandstone sample SA contains 97% of quartz, 3% of muscovite, and 0% feldspar. The sandy shale Sample SB contains 79% of quartz, 1% feldspar, and 20% muscovite. The shaly sample SC contains 69% quartz, 1% feldspar and 30% muscovite. Sample SD through SG, and all quartz sandstones, have more than 90% quartz.

The mineral detected in the sandstone facies through X-ray diffraction analysis are quartz and muscovite, while mineral of the shale facies are quartz, muscovite and kaolinite. The percentage of muscovite and kaolinite is very high in the sandy shale sample, the formation of the kaolinite might have been due to the decomposition or leaching away of orthoclase feldspar in the sample, or due to hydrothermal alteration, while muscovite could be the intermediate product in the weathering of the feldspar to kaolinite. This is because feldspar and muscovite are the most common parent minerals from which kaolin minerals are likely to originate. Alternatively, the kaolinite may have been deposited as sediment in the Cambrian paleoenvironment.

The XRF analysis indicated little and no sodium in the samples. Aluminum and Potassium tend to concentrate more in the sandy shale samples, with 35.40wt % and 6.38 wt%, respectively. This is because aluminum is derived mainly from clay minerals and feldspars, and is more abundant in shale than in sandstone due to high clay mineral content of shale (Boggs, 2006). Also potassium and magnesium content are common in clay minerals.

Table 2 shows the percentage composition of the major elements for both the sandstone and sandy shale sample. The sandstone has the highest percentage of SiO_2 which range from 97.33 to 100wt. % compared to the 60.80 to 97 wt.% of sandy shale. The TiO_2 content is high in the shale sample compared to that of sandstone, in shale samples ranges from 0.05 to 0.29wt. %. The Fe_2O_3 content in the shale sample range from 1.42 to 6.38 wt. % which is higher than that in the sandstone (<1wt.%)

MgO content in the shale sample ranges from 0 to 0.19wt. %, but Mg is not detected in sandstone samples. MnO , CaO , P_2O_5 are less than 1wt. % in all of the samples and Na_2O is not detected at all in any of the samples.

Zirconium (Zr) is the most abundant trace element in the whole sample, ranges from 26ppm to 641ppm. Rb ranges from 5ppm to 172ppm, Y range from 1ppm to 101ppm and Nb and Sr are less than 100ppm. Figure 8 shows the ratio of rubidium verses zirconium, most of the trace element in the sandstone samples show minima peaks while the sandy shale sample Sc show a maxima peak. . The relationship between Rb/Zr and $\text{K}_2\text{O/TiO}_2$ is that Rb act like K_2O , and Zr act like TiO_2 , this lead to increase in Rb and K_2O therefore increasing mica content.

5. CONCLUSIONS

Two main lithofacies types are observed in the Weisner Formation; sandstone and the shaly facies. The sandstone facies of the Weisner is more resistant to erosion and chemical weathering due to the hardness of the rock, why the shaly facies is very fragile breaks easily.

The sandstone facies have higher percentage of quartz, compare to the shaly facies which have more mica content.

There was probably humid, paleoclimate and relative tectonic stability during the Cambrian. The sandstone facies has good porosity resulting from the good sorting of the particles and therefore good reservoir potential. The sediment probably had a short transportation history as indicated from the dominantly angular and sub- angular grain shapes, suggesting deposition near the source.

Abundance of fine grained sediment indicates a shallow water environment which is an environmental condition in which shale is likely to be form, the presence of the shaly facies probably indicates formation in a marine environment.

As far as the potential for CO₂ sequestration is concerned, the formation does not offer a system to store and retain CO₂, because of the low overall porosity, diagenetically modified texture(sutured contact, long contact,) ,and presence of the shale facies.

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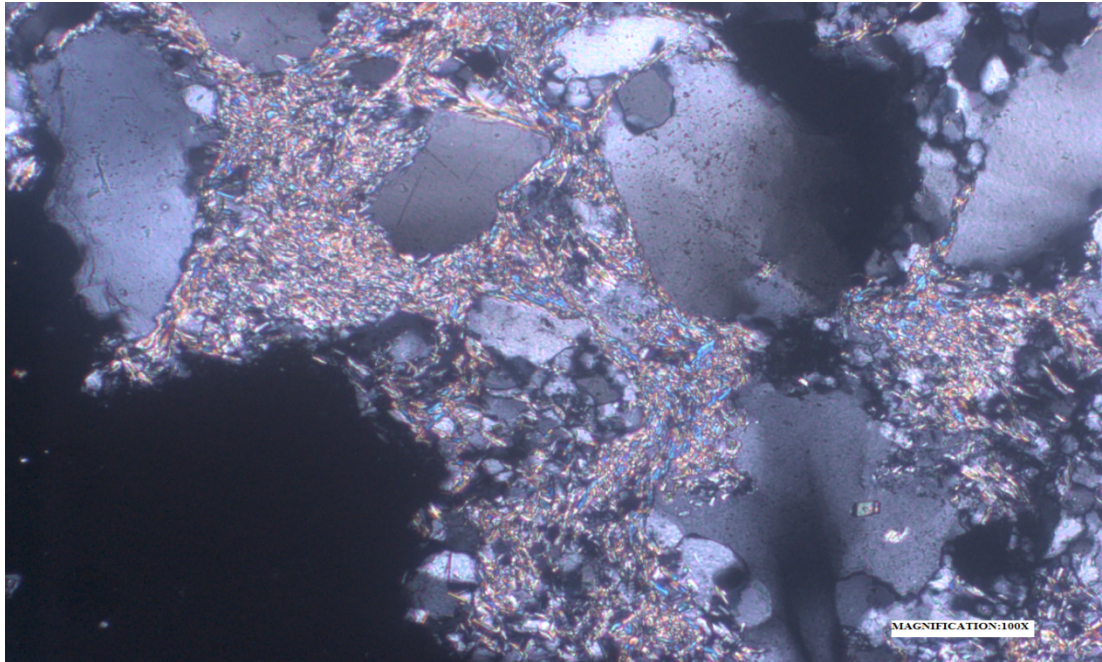
APPENDICES

1. Major element and Trace element of the Weisner Formation Samples

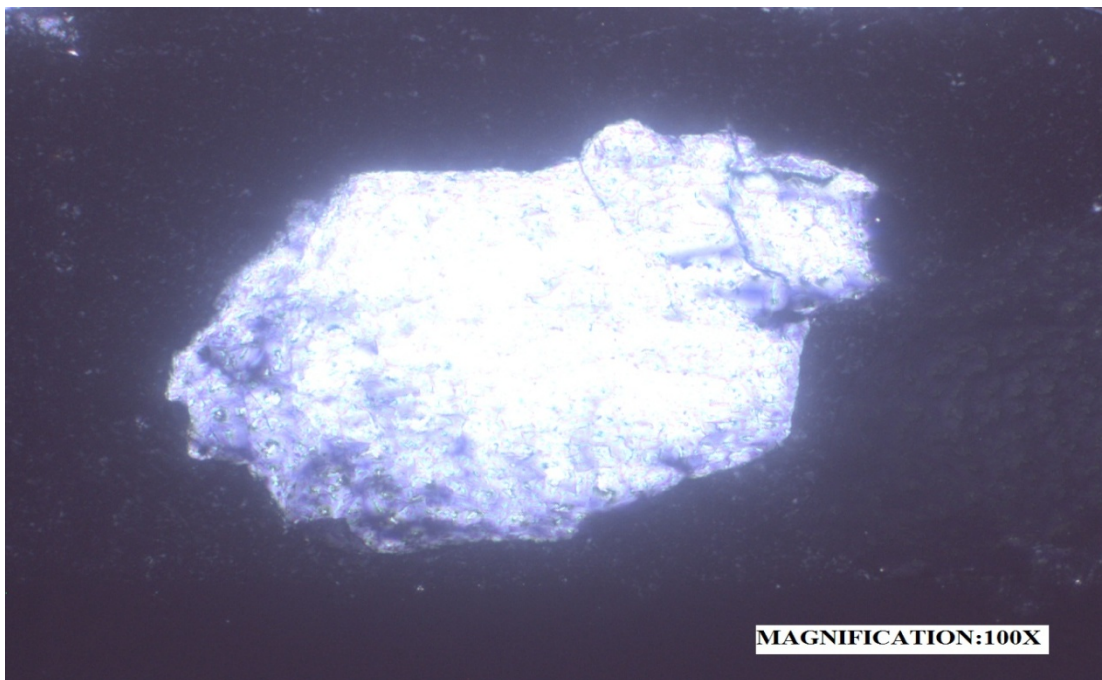
Sample	Source	Percentage Composition(Wt %)										(ppm)				
		SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Mno	Mgo	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	Rb	Sr	Y	Zr	Nb
SA	Cartersville	97.33	0.29	1.76	0.47	0.00	-0.01	0.00	-0.03	0.39	0.03	11	11	16	389	6
SB	Cartersville	101.10	0.48	4.78	1.42	0.00	0.19	0.01	-0.17	1.47	0.03	31	12	32	641	9
SC	Cartersville	68.80	1.71	35.40	2.69	0.00	1.07	0.00	-0.07	6.38	0.04	172	2	100	624	25
SD	Cartersville	106.20	0.11	0.84	0.81	0.05	-0.03	0.04	-0.03	0.18	0.03	9	3	3	67	8
SE	Cartersville	91.77	0.08	1.40	0.37	0.00	-0.07	0.02	-0.25	0.33	0.03	6	2	2	53	1
SF	Cartersville	109.28	0.18	1.68	0.87	0.00	-0.02	0.02	-0.26	0.48	0.02	8	5	7	145	7
SG	Cartersville	101.32	0.05	0.49	0.90	0.00	-0.07	0.03	-0.17	0.06	0.03	5	5	1	26	5

Major element and Trace element data from XRF Analysis of Cartersville samples (Weisner Formation).

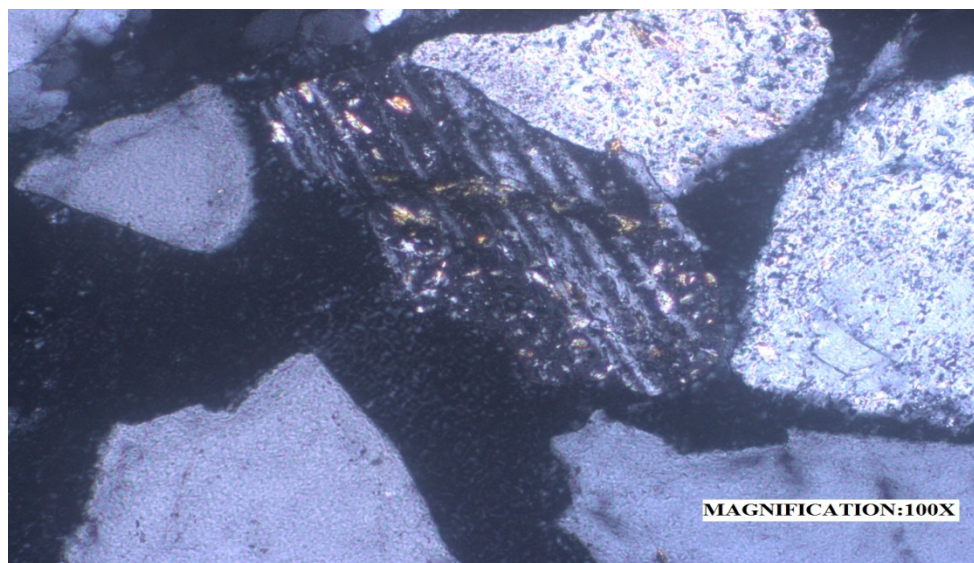
2. Photomicrograph of the Weisner Formation Samples



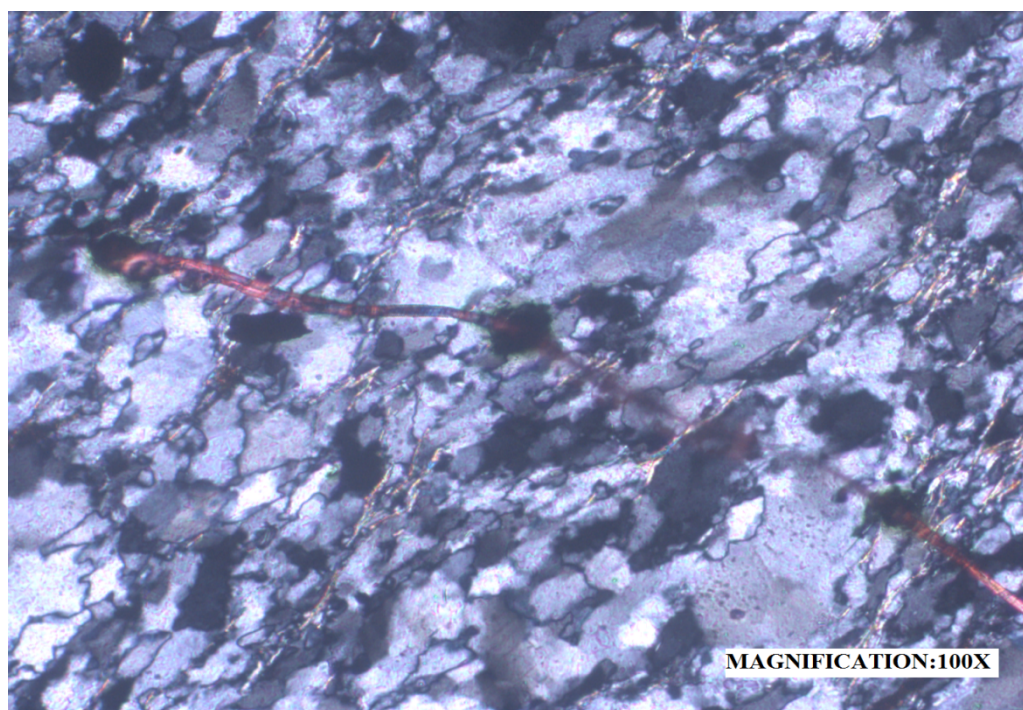
Photomicrograph of sandstone sample SA showing abundant of mica grains.



Photomicrograph of sandstone sample SB2 showing quartz floating in matrix.

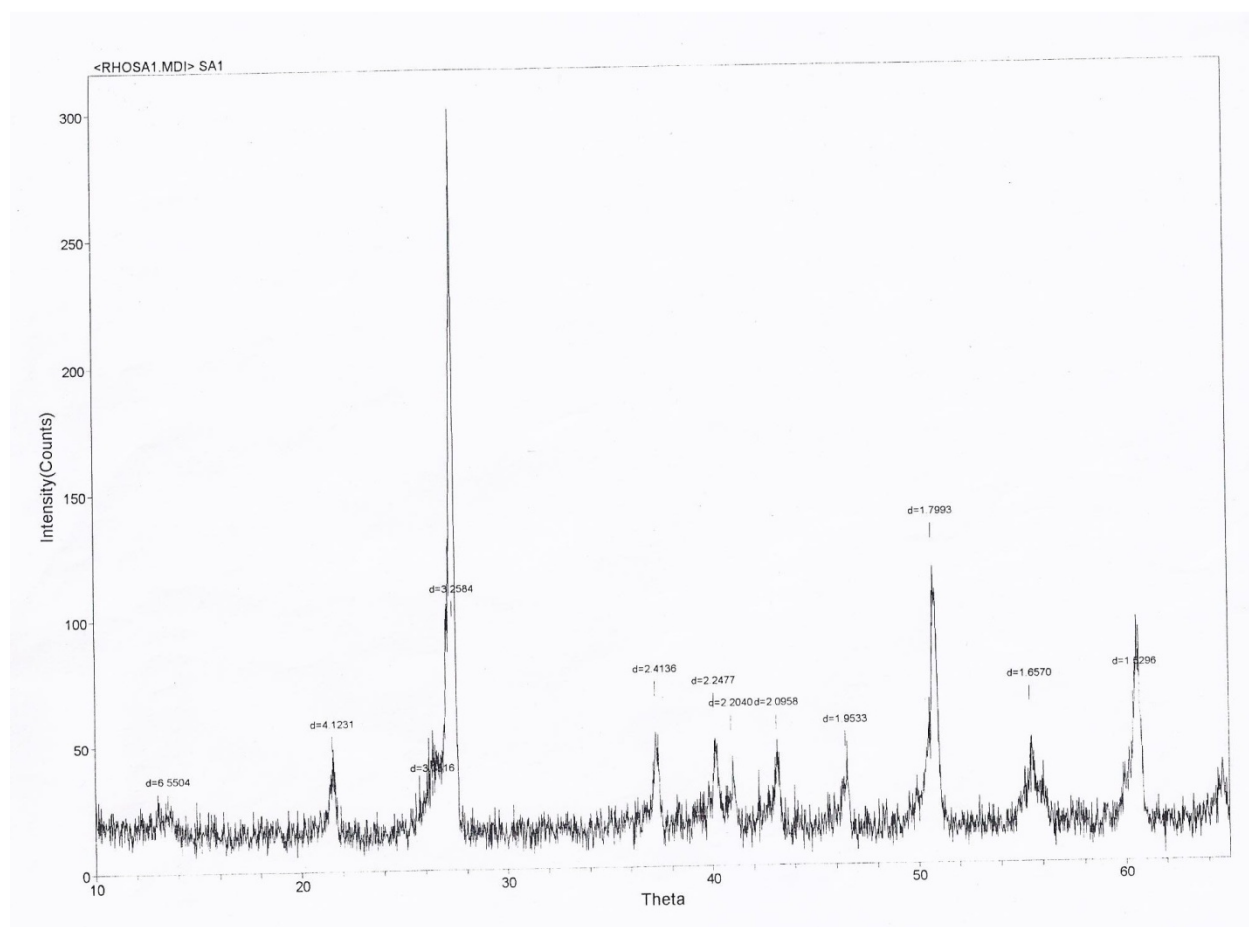


Photomicrograph of sandstone sample SD showing highly fractured muscovite.

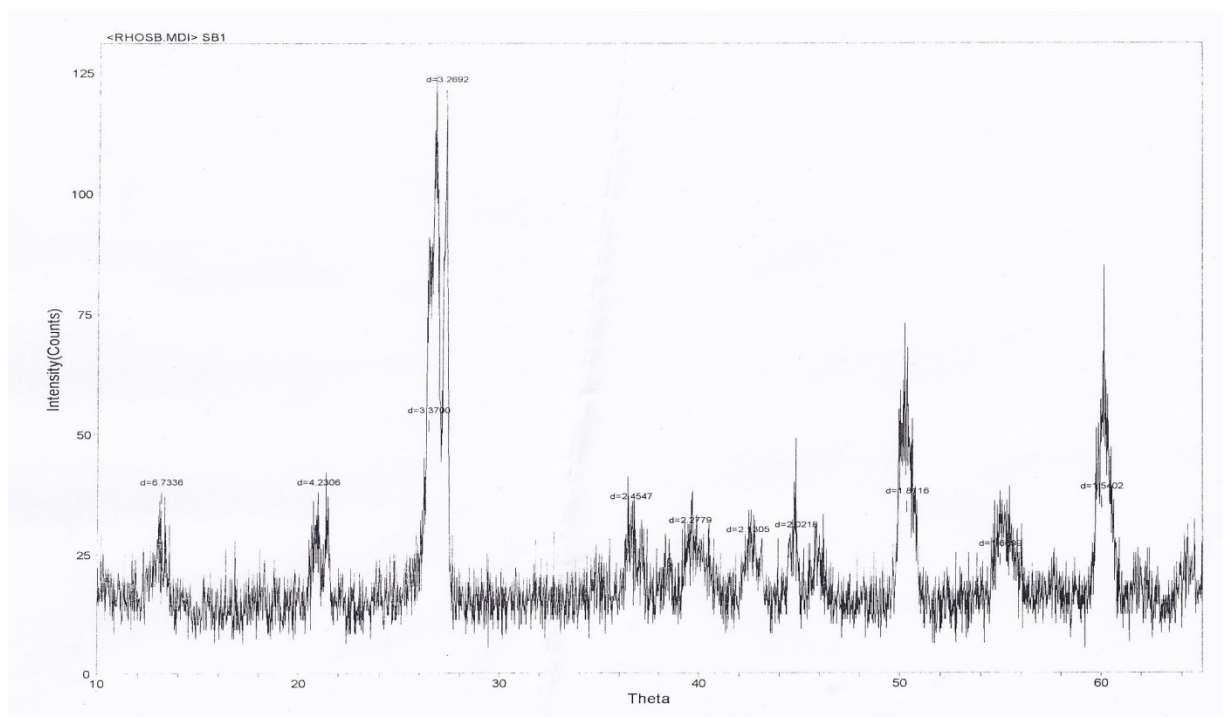


Photomicrograph of sandstone sample SE.

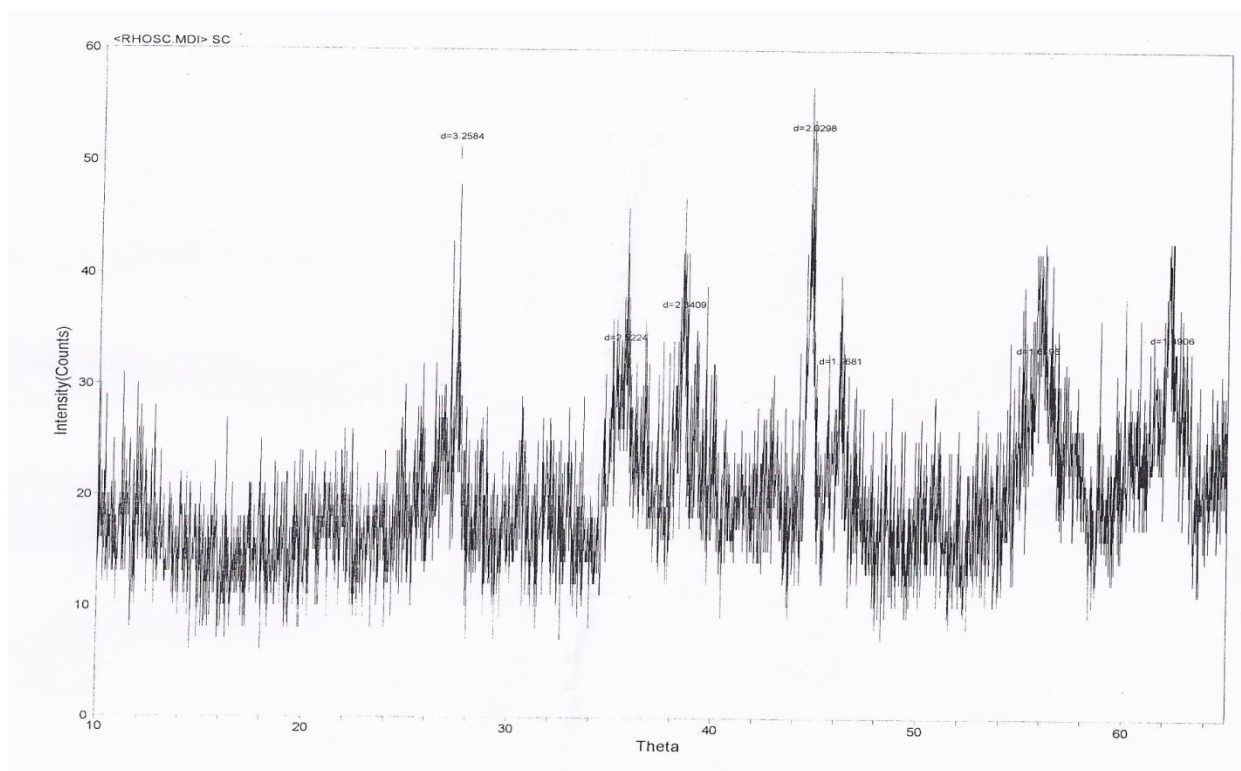
3. X-ray diffraction patterns of the Weisner Formation Samples using Philips X-ray diffractometer at Georgia State University with a Random back filled mounts, scanned from 10 degree 2θ to 60 degree 2θ and X- ray generated at 35Kv and 15mA.



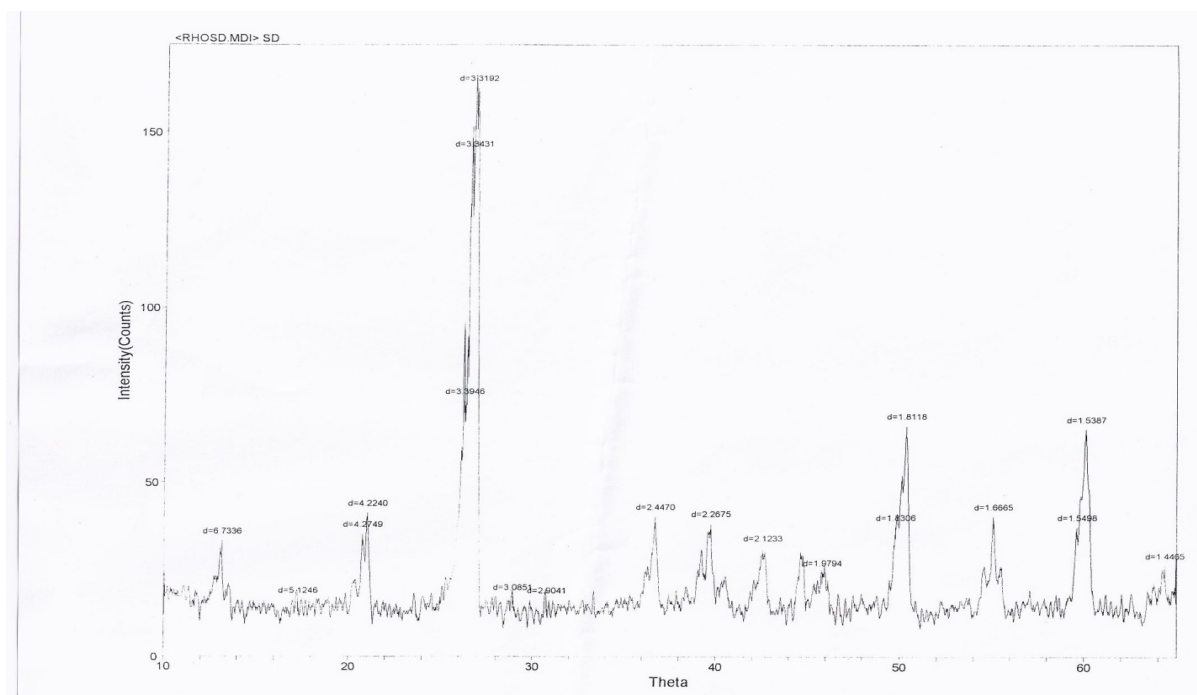
X-ray diffraction pattern sample SA (Sandstone).



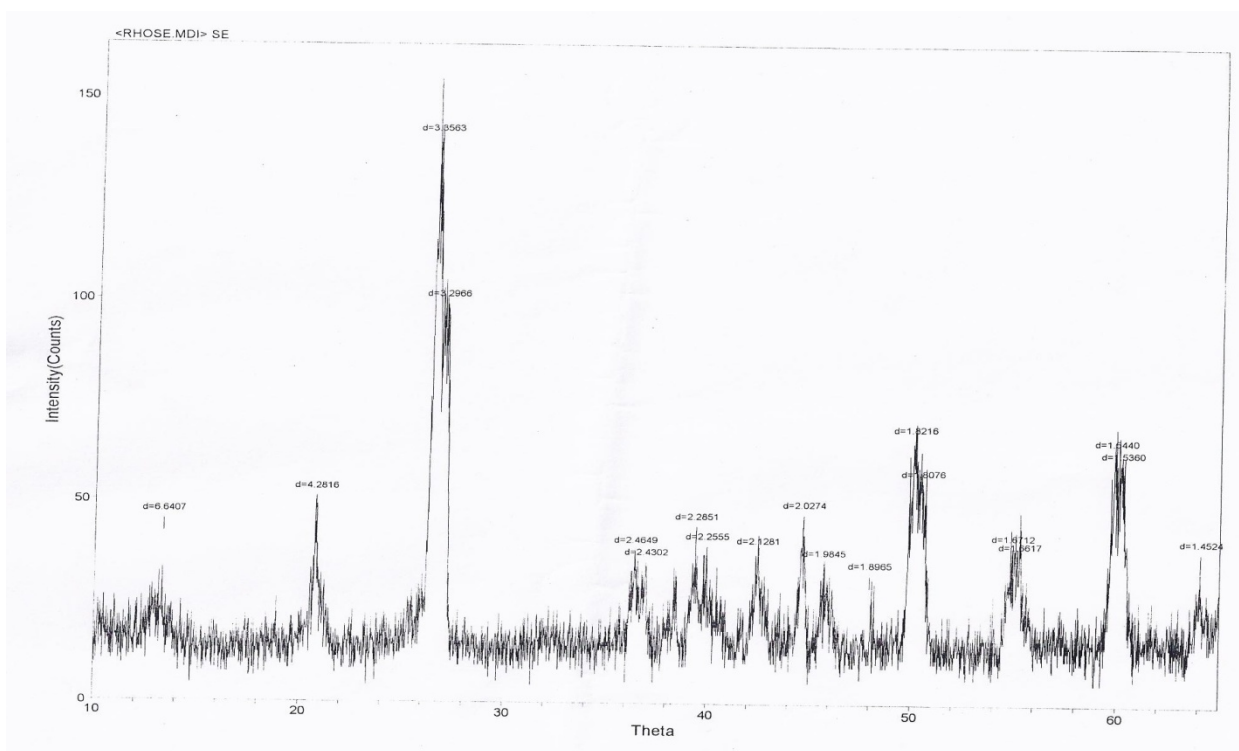
X-ray diffraction pattern sample SB (Sandy shale).



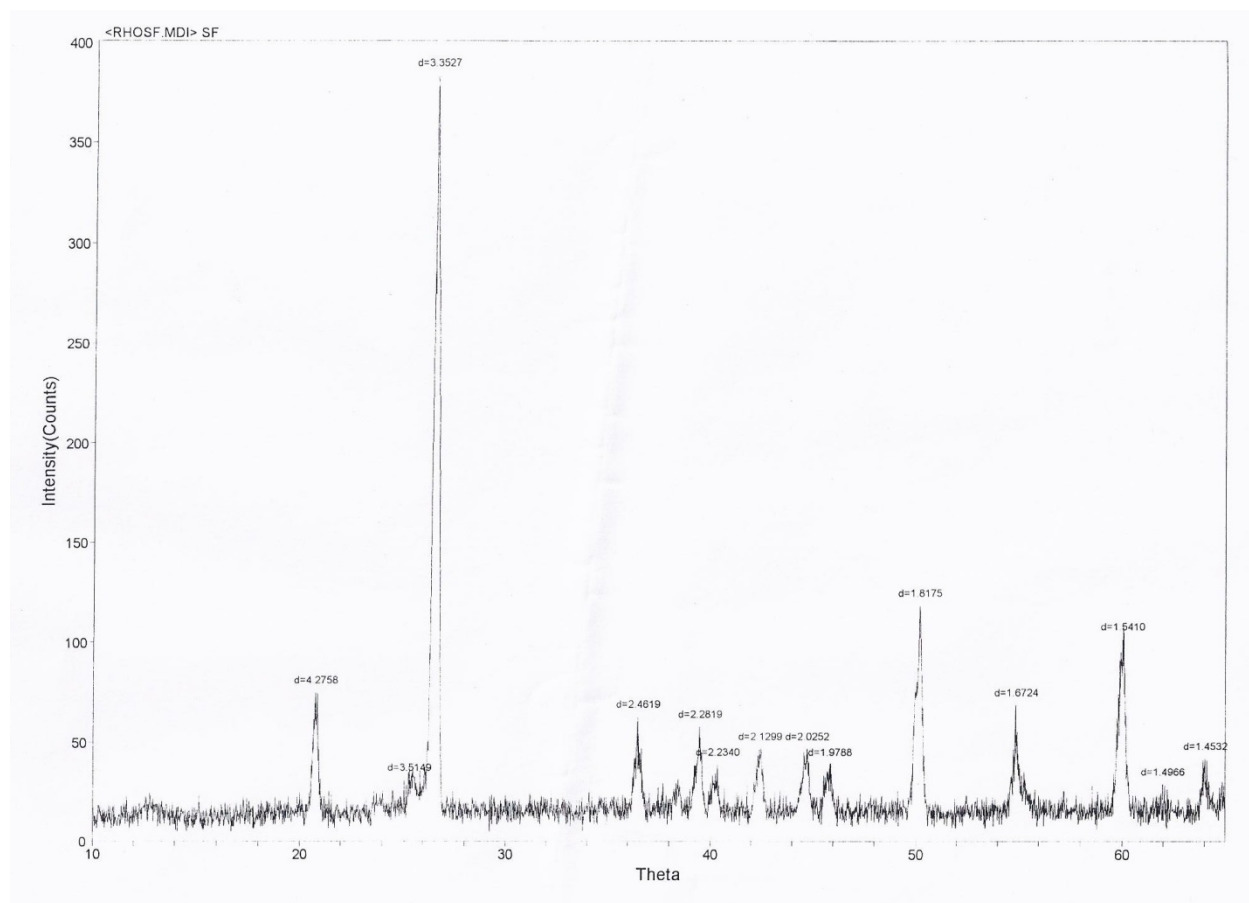
X-ray diffraction pattern sample SC (Sandy shale).



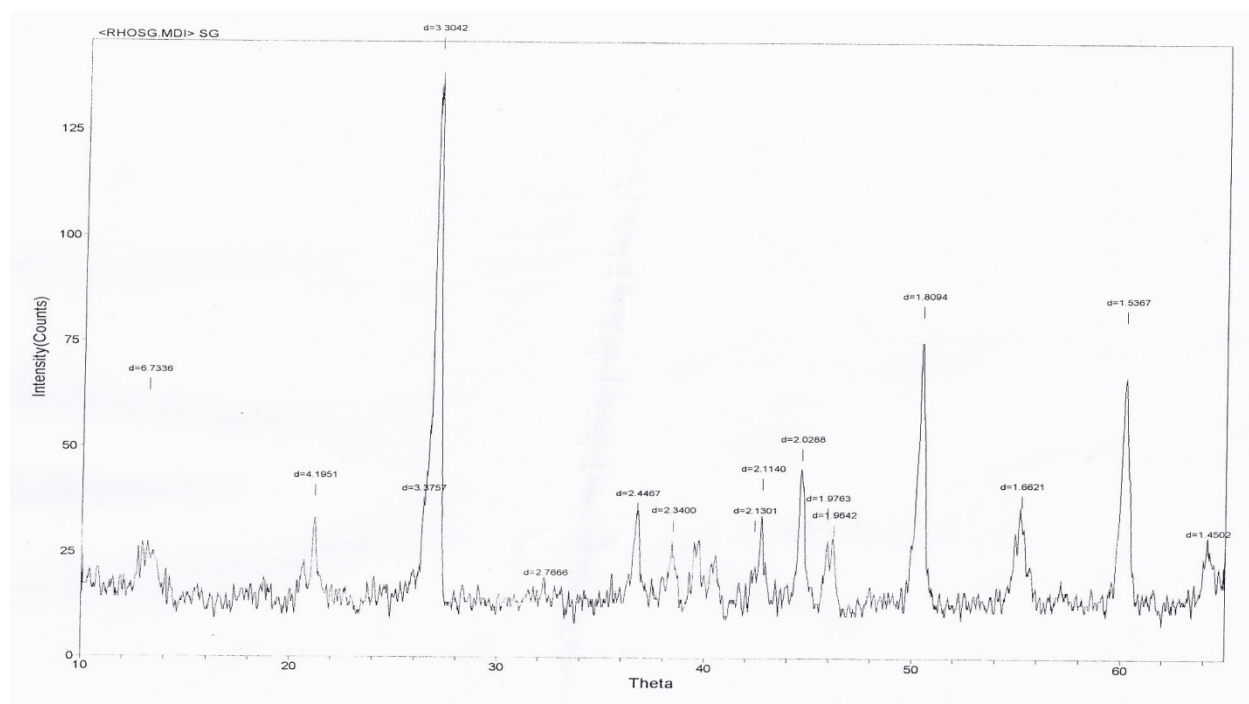
X-ray diffraction pattern sample SD (Sandstone).



X-ray diffraction pattern sample SE (Sandstone).



X-ray diffraction pattern sample SF (Sandstone).



X-ray diffraction pattern sample SG (Sandstone).